October 1959
75¢

EMICONDUCTOR PRODUCTS

Transistorized TV Tuner

Production Method For Measuring Rise, Fall and Storage Time

Microwave Frequency Multiplication and Division

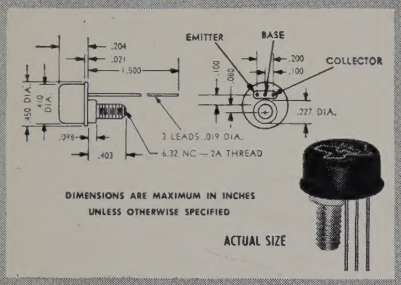
Flow Graph Analysis of Feedback Networks

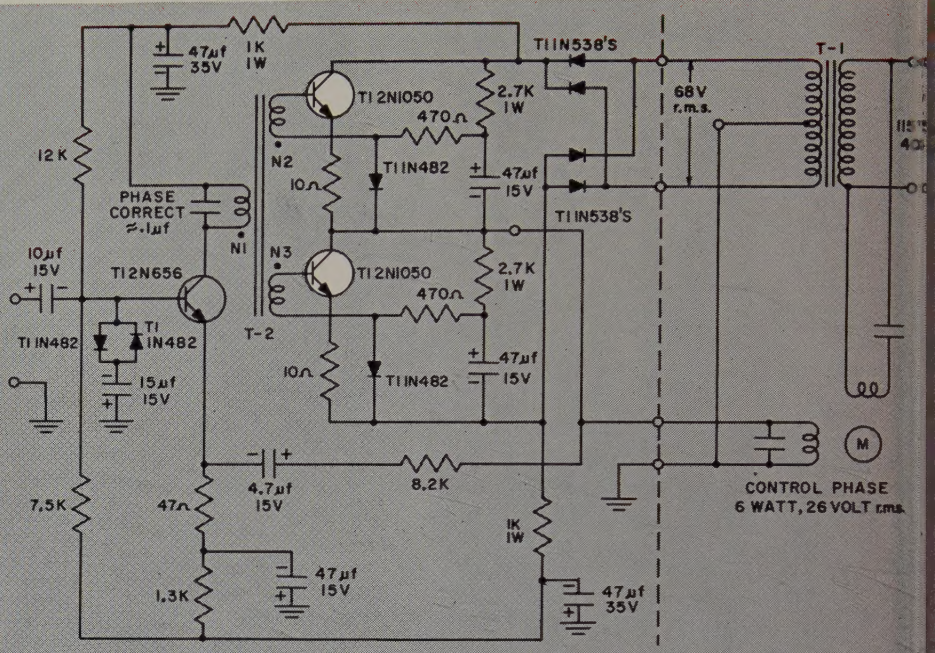
How to get 55% over-all efficiency i transistorized 6-watt servo amplifie

HIGH-EFFICIENCY SERVO CIRCUIT REQUIRES . . .

- **no output transformer**
- **no center-tap motor winding**

Higher over-all efficiency than in a conventional Class-B push-pull amplifier is achieved in this servo by use of unfiltered rectified a-c for current supply voltage—with resulting reduction in size, weight and power supply requirements. This higher efficiency means greater transistor reliability, smaller heat sink and/or higher allowable ambient temperatures. Output will remain sinusoidal when amplifier is overdriven.





TRANSFORMERS

T-1 400 cps, 12-watt power transformer step-down 115 volt to 68 volt c.t.

T-2 400 cps, 65-mw driver transformer. Turns ratio N1: N2: N3 = 2: 1: 1
Primary Current = 10 ma d-c. Primary Inductance = 1.5 hy.

...with TI 2N1050 N-P-N silicon transistors

Exclusive TI 2N1047 intermediate-power series now gives you maximum design flexibility plus high efficiency . . . all in a miniature package!

Consider the design flexibility made possible by the exclusive features of this series . . . 40 watts dissipation at 25°C case temperature . . . unique stud mounting for maximum thermal efficiency . . . 80- and 120-volt BV_{CEX} . . . 15-ohm R_{CS} . . . −65°C to +200°C operati and storage range . . . choice of beta spreads.

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Write on your company letterhead for illustrated TI APPLICATION NOTES on the transistorized servo amplifier.

PARAMETER	TEST CONDITIONS		2N1047		2N1048		2N1049		2N1050		
			min.	max.	min.	max.	min.	max.	min.	max.	un
BV_{CEX} Breakdown Voltage	$I_C = 250\ \mu a$	$V_{BE} = -1.5V$	80		120		80		120		V
BV_{EBO} Breakdown Voltage	$I_E = 250\ \mu a$	$I_C = 0$	10		10		10		10		V
I_{CBO} Collector Cutoff Current	$V_{CB} = 30V$	$I_E = 0$		15		15		15		15	µ
h_{FE} Current Transfer Ratio †	$V_{CE} = 10V$	$I_C = 200ma$	12	36	12	36	30	90	30	90	—
h_{IE} Input Impedance †	$V_{CE} = 10V$	$I_B = 8ma$		500		500		500		500	oh
R_{CS} Saturation Resistance †	$I_C = 200\ ma$	$I_B = 40ma$		15		15		15		15	oh
V_{BE} Base Voltage †	$V_{CE} = 15V$	$I_C = 500ma$		10		10		10		10	V

†Semiautomatic testing is facilitated by using pulse techniques to measure these parameters. A 300-microsecond pulse (appr mately 2% duty cycle) is utilized. Thus, the unit can be tested under maximum current conditions without a significant increase junction temperature, even though no heat sink is used. The parameter values obtained in this manner are particularly perti for switching circuit design and, in general, indicate the true capabilities of the device.

germanium and silicon transistors
silicon diodes and rectifiers
tan-Ti-cap solid tantalum capacitors
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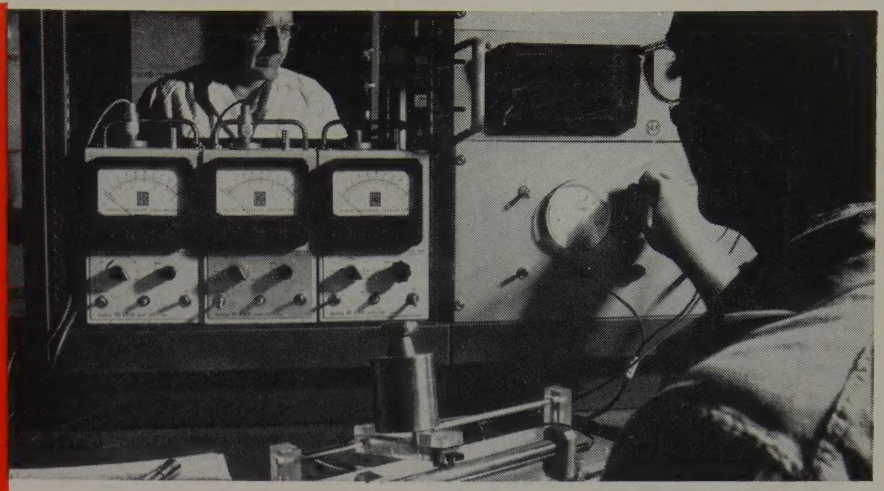
MERCK HAS ALL FOUR FORMS OF Silicon IN PRODUCTION QUANTITIES



Measuring resistivity with digital voltmeter at Merck Control Laboratory, Danville, Pa.

***MERCK DOPED SINGLE CRYSTAL SILICON**—offers doped float zone refined single crystals of high quality at low costs. Yields of usable material are reported to be especially high when device diffusion techniques are used with these crystals. Float zone single crystals doped either "p" or "n" type with resistivities from *0.1 to 300 ohm cm.* any range plus or minus 25% with high lifetimes, available in diameters of 19 to 21 mm., and random lengths of 2 to 10 inches.

NOTE: *Doped single crystals float zone refined in other diameters, resistivities, or lifetimes not listed above can be furnished as specials.*

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***NOTE:** *Extended resistivity range.*

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For additional information on specific applications and processes, write Merck & Co., Inc., Electronic Chemicals Division, Department SP-109, Rahway, New Jersey.

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NPN High Speed, High Gain Switches

NPN High Frequency and Video Amplifiers

Close parameter control

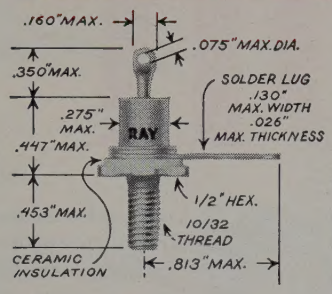
Up to 50 megacycles minimum f_{ab}

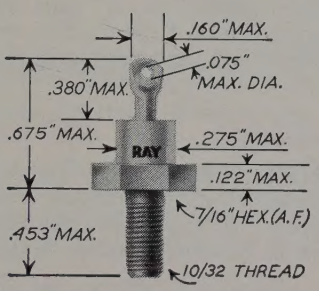
High Voltage PNP Fusion Alloy Transistor

$V_{CBO} = -100$ volts max.

$V_{CEO} = -80$ volts max.

$V_{EBO} = -60$ volts max.





New 4 Amp Silicon Rectifiers (Temperature Range −65°C to +165°C)

NON-INSULATED		INSULATED STUD	Peak Operating Voltage −65°C to +165°C volts	Ave. Rectified Current		Reverse Current max. μA at Specified Volt		
Cathode to Stud	Anode to Stud			25°C amps.	150°C amps.	25°C	150°C	V
1N2512	**1N2512R**	**1N2518**	100	4.0	1.0	2.0	250	1
1N2513	**1N2513R**	**1N2519**	200	4.0	1.0	2.0	250	2
1N2514	**1N2514R**	**1N2520**	300	4.0	1.0	2.0	300	3
1N2515	**1N2515R**	**1N2521**	400	4.0	1.0	2.0	300	4
1N2516	**1N2516R**	**1N2522**	500	4.0	1.0	2.0	350	5
1N2517	**1N2517R**	**1N2523**	600	4.0	1.0	2.0	400	6

NEW RAYTHEON GERMANIUM TRANSISTORS

Complementary circuitry with Raytheon PNP types

Highest reliability

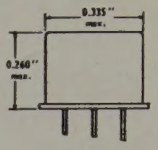
Excellent fast switching characteristics

Low saturation voltage

High Speed Switches (Temperature Range −65°C to +175°C)

Type	V_{CB} max. volts	I_{CO} V_{CB} = 6 volts max. μA	V_{EB} max. volts	H_{FE} I_C = 10 ma V_{CE} = 5 volts min.	V_{SAT} I_C = 5 ma I_b = 2.5 ma max. volts	f_{ab} I_E = 1 ma V_{CE} = 6 volts ave. Mc	R_b ave. ohms	C_{ob} ave. μμf
N1386	25	.1	3	30	.6	60	60	3.5
N1387	30	.1	3	20	.6	50	60	3.5

TO-5

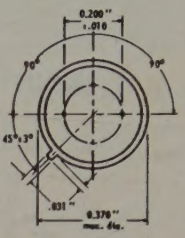


High Frequency and Video Amplifiers (Temperature Range −65°C to +175°C)

Type	V_{CB} max. volts	I_{CO} V_{CB} = 15 volts max. μA	F_t V_{CE} = 6V I_E = 1 ma Mc	R_{in}* at 10 Mc ave. ohms	R_{out}* at 10 Mc ave. ohms	Power Gain at 10 Mc ave. decibels	Gain-Bandwidth Product ave. Mc
N1388	45	.5	60	500	5000	20	75
N1389	50	.5	30	500	5000	15	45
N1390	20	.8 @ 6V	12	400	6000	12	—

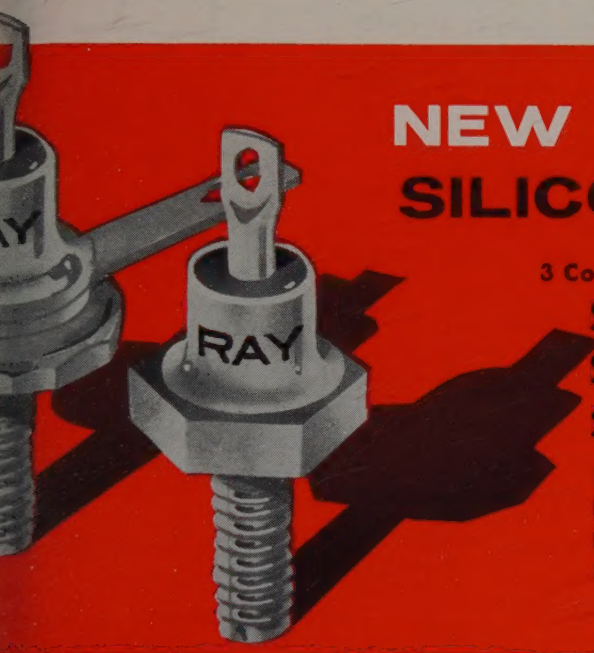
*Measured resistive component of the impedance

E3-44



High Voltage PNP (Temperature Range −65°C to +160°C)

Type	V_{CB} max. volts	V_{CE} max. volts	I_{CO} max. μA	H_{FE} I_B = 0.1 mA V_{CE} = −0.5 V ave.	R_{SAT} max. ohms	V_{EB} max. volts
N1275	−100	−80	1.0	15	60	−60



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3 Constructions for design and operating convenience

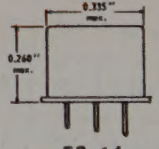
STUD INSULATED
STUD CONNECTED TO CATHODE
STUD CONNECTED TO ANODE

Low reverse current
High forward conductance
Fast reverse recovery
Exceptional stability

N Switches — Medium Current High Frequency, High Gain (Temperature Range −65°C to +85°C)

Type	V_{CB} max. volts	f_{ab} min. Mc	H_{FE} ave. I_C = 50 mA V_{CE} = 1.0 V	R_{SAT} ave. ohms
2N438	25	2.5	25	2
2N439	20	5.0	45	2
2N440	15	10.0	70	2

TO-5

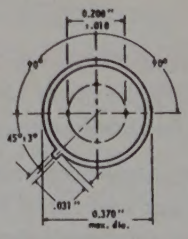


High Gain IF and Converter For Broadcast and Auto Radio (Temperature Range −65°C to +85°C)

Type	Circuit Usage	V_{CE} max. volts	I_{CO} max. μA	C_{ob} f = 1 Mc ave. μμf	Gain 455 Kc db
2N1366	Converter	12	20	11	28*
2N1367	IF	12	20	11 ± 3	38

*Conversion Gain

E3-44



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RCA TYPE NUMBERS	Peak Inverse Voltage (VOLTS)	RMS Supply Voltage (VOLTS)	DC Reverse Voltage (VOLTS)	FORWARD CURRENT, DC 50°C Ambient (MA)	100°C Ambient (MA)	150°C Ambient (MA)	Surge One-Cycle (AMP)	AMBIENT TEMPERATURE Operating (°C)	Storage (°C)	CHARACTERISTICS at Ambient Temp. of 25°C: Max. Forward Voltage Drop (DC) at indicated DC Forward Current (VOLTS)	Max. Reverse Current (DC) at Max. Peak. Inverse Voltage (μa)	at Ambient Temp. of 150°C: Max. Reverse Current (averaged over one complete cycle) at Max. Peak. Inverse Voltage (μa)
IN536	50	35	50	750	500	250	15	−65 to +165	−65 to +175	1.1 at 500 ma	5	400
IN537	100	70	100	750	500	250	15	−65 to +165	−65 to +175	1.1 at 500 ma	5	400
IN538	200	140	200	750	500	250	15	−65 to +165	−65 to +175	1.1 at 500 ma	5	300
IN539	300	210	300	750	500	250	15	−65 to +165	−65 to +175	1.1 at 500 ma	5	300
IN540	400	280	400	750	500	250	15	−65 to +165	−65 to +175	1.1 at 500 ma	5	300
IN1095	500	350	500	750	500	250	15	−65 to +165	−65 to +175	1.2 at 500 ma	5	300
IN547	600	420	600	750	500	250	15	−65 to +165	−65 to +175	1.2 at 500 ma	5	350

6 Types for MAGNETIC-AMPLIFIER applications requiring exceptionally low-leakage currents

IN440-B	100	70	100	750	500	250	15	165	−65 to +175	1.5 at 750 ma	0.3	100
IN441-B	200	140	200	750	500	250	15	165	−65 to +175	1.5 at 750 ma	0.75	100
IN442-B	300	210	300	750	500	250	15	165	−65 to +175	1.5 at 750 ma	1.0	200
IN443-B	400	280	400	750	500	250	15	165	−65 to +175	1.5 at 750 ma	1.5	200
IN444-B	500	350	500	650	425	0	15	150	−65 to +175	1.5 at 750 ma	1.75	200
IN445-B	600	420	600	650	400	0	15	150	−65 to +175	1.5 at 750 ma	2.0	200

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- 100% forward characteristic test
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Front Cover

Transistorized TV Tuner designed by General Instrument Corporation for "No-Plug-In" battery-powered TV sets. Operates on only 1/25th of the electrical power needed for standard tuners, packs 287 separate parts into 15 cubic inches of space. Weighs 9½ ounces. Uses 3 specially-designed transistors—oscillator, mixer and R. F. Two years in development, the new Tuner is only 1¾" high, 2½" wide and 3½" deep. Tuner operates on 12 volts with a current drain of 8.5 milliamperes. Conventional tube types require approximately 130 volts at 20.0 milliamperes. (An article on this device will appear in a future issue of "Semiconductor Products.")

SEMICONDUCTOR PRODUCTS is published monthly by Cowan Publishing Corp. Executive and Editorial Offices: 300 West 43rd Street, New York 36, N. Y. Telephone: JUdson 2-4460. Subscription price: $6.00 for 12 issues in the United States, U. S. Possessions, APO, FPO, Canada and Mexico, $8.00 for 12 issues. All others: 12 issues $10.00. Single Copy 75¢. Accepted as controlled circulation publication at Bristol, Conn.

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UNIT TYPE	CAPACITANCE @ −4 Vdc uuf. ± 20%	Approx. Range uuf.*	MAXIMUM WORKING VOLTAGE VOLTS DC	MINIMUM Q @ 50 MC @ −4 Vdc	Q @ 50 MC AND MAXIMUM WORKING VOLTAGE
CS-10	10	5-30	25	20	50
CS-15	15	7-40	25	20	50
CS-20	20	10-55	25	20	50
CS-30	30	15-80	25	18	45
CS-40	40	20-100	25	18	45
CS-50	50	25-125	25	16	40
CS-60	60	30-150	25	16	40
CS-70	70	35-175	25	14	30
CS-80	80	45-205	25	14	30
CS-90	90	50-225	25	13	25
CS-100	100	55-250	25	12	20

*Capacitance range specified from .1 volts to maximum working voltage.

UNIT TYPE	CAPACITANCE @ −4 Vdc uuf. ± 20%	Approx. Range uuf.*	MAXIMUM WORKING VOLTAGE VOLTS DC	MINIMUM Q @ 50 MC @ −4 Vdc	Q @ 50 MC AND MAXIMUM WORKING VOLTAGE
CS-10A	10	2-25	100	15	35
CS-15A	15	4-40	100	15	35
CS-20A	20	5-55	100	15	35
CS-30A	30	10-80	100	13	30
CS-40A	40	15-100	100	13	30
CS-50A	50	20-120	100	11	25
CS-60A	60	25-140	75	11	25
CS-70A	70	30-170	75	10	20
CS-80A	80	35-200	50	10	20
CS-90A	90	40-220	50	9	15
CS-100A	100	45-240	50	8	13

*Capacitance range specified from .1 volts to maximum working voltage.

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708 S. Sheridan, P. O. Box 5423, Tulsa

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Seattle Radio Supply Co.
2115 Second Ave., Seattle

WISCONSIN
Radio Parts Co., Inc.
1314 N. 7th St., Milwaukee

Editorial . . .

Masers

Efforts in the design of low noise, very high frequency amplifiers have produced the maser, the parametric amplifier, and the tunnel diode. These represent different techniques and possess different characteristics, but do have some common underlying principles.

The maser must be operated at extremely low temperature and for this reason appears less attractive than the other devices. However, it has far higher frequency capabilities, and possibly may be used at infrared and optical frequencies.

The fundamental principle of the maser consists of the generation of radiations by transitions of electrons from a high to a low energy level. Since the frequency of the radiation is related to the corresponding energy jump by the Bohr law

$$h\,f = W_m - W_n$$

it follows that for the generation of optical frequencies energy jumps of the order of electron volts are needed; and for the generation of microwave frequencies energy jumps of the order of 10^{-5} electron volts are sufficient. Energy levels with the required separation are readily obtained with a number of paramagnetic materials in which the electrons possess a net magnetic dipole moment, and therefore may be separated by application of a magnetic field. The corresponding separation of energy levels (Zeeman effect) is given by the relation

$$h\,f = \frac{\mu_o\, qh}{4\,\pi\, m}\, g\,\Delta\, H$$

where g is a factor equal to or larger than one (Landé factor).

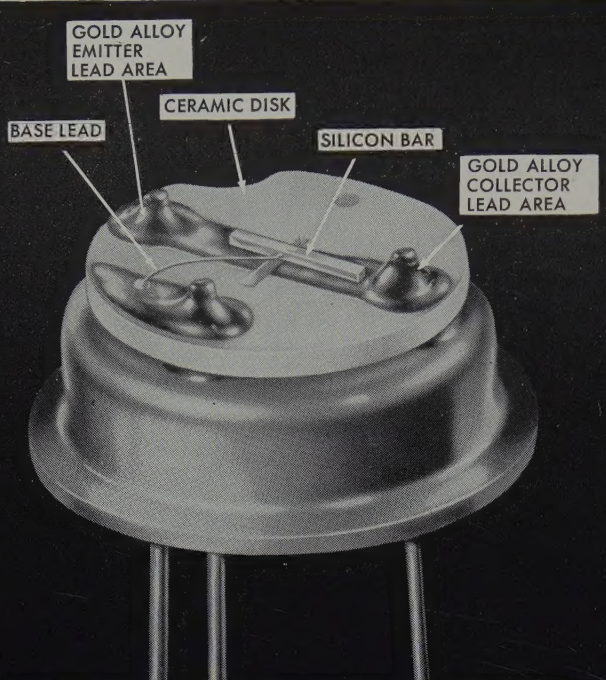
In order to stimulate such radiations a displacement of the density distribution of the electrons in the various levels from the equilibrium condition must be created. If only two levels are available, this may be obtained with an intermittent operation, applying short pulses of appropriate frequency. If three energy levels are available, a continuous operation is possible, bringing electrons from the lowest to the highest level and letting them decay. In the latter case certain conditions must be satisfied by the energy differences and the relaxation times of the corresponding transitions. Since the equilibrium densities of the electrons in the various levels are proportional to the quantities $exp(-\ W\ /kT)$, it is convenient to decrease the temperature as much as possible, to increase the said densities. This is also favorable in reducing the amount of spontaneous emission which always accompanies the stimulated emission and which represents noise.

Various techniques have been proposed for the pumping of electrons from low to high energy level. The paramagnetic material may be placed in a wave guide; but more conveniently it is placed in a cavity which resonates at both the pumping and the emission frequencies.

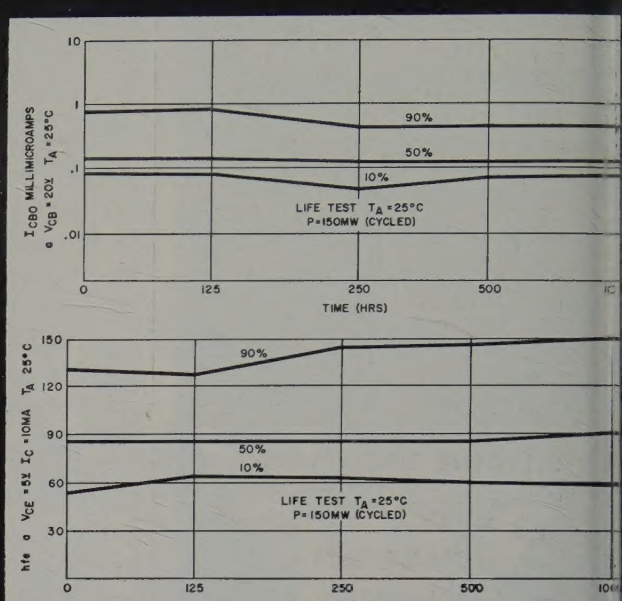
When the device is used as an oscillator, it is found to possess a very narrow frequency band, and therefore also a high frequency stability; when it is used as an amplifier, however, the narrowness of the bandwidth is less convenient. The resultant noise of the device is a function of the amount of spontaneous emission, and also depends on the feedback of the load noise. The latter may be minimized with the use of appropriate nonreciprocal unilateral devices ("circulators"). For example a three level maser using potassium chromicyanide designed at Lincoln Laboratories had the following characteristics: Temperature of operation 1.25° K, pump frequency 9400 *mc*, pump power 4 *mw*, stimulated emission frequencies 1900 *mc* and 2800 *mc*, bandwidth 180 *kc* at 2800 *mc*, noise figure of the order of 0.3 *db*.

Samuel L. Marshall

New life test data prove superior



Magnified photo of silicon transistor showing Fixed Bed Construction. All parts are firmly fastened, with no suspended parts except wire lead. Transistor reacts as a solid block in resisting shock and vibration.



Charts show extreme stability of performance throughout 1000 hours of life for beta and I_{CBO}. Test conditions were 150 mw at 25°C, 200°C storage and 25 mw at 125°C. Drift rates were substantially the same under all conditions.

New NPN Tetrodes: Higher gain at high temperature and low current

LARGE QUANTITIES OF TYPES 3N36 AND 3N37 TESTED AND PROVED, HIGH RELIABILITY THE RESULT OF TWO YEARS OF MANUFACTURING EXPERIENCE*

Test	Results	% Survival
Mechanical Reliability		
3-ft drop-shock (2500 G's. Mil St'd calls for 500G's)	2 out of 595 did not survive	99.66
Temperature cycling (−55°C to 100°C)	1 out of 375 did not survive	99.78
Life Test Reliability		
Cycled power @ 50 mw (device rated at 30 mw)	6 out of 500 exceeded parameter limits at 1000 hours	98.8
Oven @ 85°C	17 out of 500 exceeded parameter limits at 1000 hours	96.8
Shelf	No parameter failures of 500 units at 1000 hours	100.0

*General Electric's rigid standards call for only a slight shift in parameters to be a "failure." Many of these "failures" are still within EIA limits.

Here are two new germanium transistors that ope on lower voltages, require less current and are m rugged (see box below) than any other transistors perform a like function. Furthermore, they delive high and constant gain at various voltages and at power dissipation levels. Therefore, they are not useful at high temperatures, but they also simplify cuit design and eliminate the need for close vol regulation.

Features: Maximum gain at 1 ma, 5 volts or 5 mw. gain noise factor from 1 ma to 5 ma. *Where to use th* Mobile communications (made possible the first t sistorized portable receiver). Wide band amplifier, o lator and switching applications for radar and vide frequencies to 200 mc. *Availability:* Now . . . from y General Electric Semiconductor Sales Representative in stock at your G-E Semiconductor Distributor's.

Absolute Maximum Ratings (25°C)	2N36	2N37	
Collector voltage to base 1 or base 2 (V_{CB})	+7	+7	V
Emitter to base 1 or base 2 (V_{EB})	+2	+2	V
Collector current (I_C)	+20	+20	ma
Emitter current (I_E)	−20	−20	ma
Base 2 current (I_{B2})	2	2	ma
Total Power dissipation	30	30	mw

Electrical Characteristics (25°C)		
Output capacity (C_{ob})	2	1.5
Noise figure (NF)	11	11
Input impedance (h_{ie})	100-j27	80-j10
Current transfer ratio (h_{fe})	$2.2\angle -81°$	$1.1\angle -100°$
Common base cutoff frequency (f_{ab})	50 MIN.	90 MIN.
Common Emitter power gain (G_e)	11.5	9
Measurement frequency	60	150

tability of G-E silicon transistors

Uniform characteristics out to 1000 hours exhibited by silicon transistors featuring Fixed Bed Construction

Comprehensive tests performed on General Electric silicon transistors show remarkably stable performance throughout 1000 hours of operation at high temperatures. Each test was run on seven lots of fifty Type 2N337 or 2N338 transistors (part of the series 2N332 through 339). These are the results:

350 units were given a 150 mw operating test at 25°C.

Only two units exceeded parameter limits, a successful performance rate of 99.4 percent.

350 units were given a 200°C storage test.

Only three units exceeded parameter limits, a successful performance rate of 99.1 percent.

Fixed Bed Construction, plus stabilized processing makes these results possible. No fluxes, resins or solders are used — only a gold alloy which forms an integral bond between all parts.

Besides the demonstrated electrical characteristics, General Electric's silicon transistors can absorb physical punishment far beyond normal specifications. All parts are solidly fixed together and react as a solid block in resisting shock and vibration. Test units have been fired from a shotgun, struck with a golf club and rattled freely in an auto hubcap for 700 miles—and worked afterward.

Electrically and mechanically, this series of transistors is the most thoroughly tested and proved today—your assurance of high stability and reliability. Call your General Electric Semiconductor Representative for further details.

ABSOLUTE MAXIMUM RATINGS AT 25°C

	2N332-6	2N337-8	
Collector to base voltage	45	45	volts
Emitter to base voltage	1	1	volt
Collector current	25	20	ma
Collector power dissipation	150	125	mw
Operating temperature	−65°C to 175°C	−65° to 150°C	

Absolute Maximum Ratings at 25°C

Collector to base voltage	20 volts
Emitter to base voltage	15 volts
Collector to emitter voltage	20 volts
Collector current	300 ma
Base current	50 ma
Emitter current	300 ma
Storage temperature	85°C to −65°C
Operating junction temperature	85°C
Power dissipation	150 mw

Now available—4 new NPN alloy transistors

Four new germanium switching transistors, made by the highly controllable NPN alloying process, are now being warehoused by General Electric and its distributors. The four transistors, Types 2N634, -5, -6 and 2N388, feature extremely consistent parameters. I_{CO} for instance, multiplies up in a normal fashion, so that higher temperature I_{CO} may be predicted from low temperature readings.

The transistors provide 150 mw power dissipation. They are useful in emitter-follower applications in computers, high current flip-flops, and are ideal as complementary devices to PNP computer transistors, such as the 2N396.

For complete information call your General Electric Semiconductor Sales Representative, your G-E Semiconductor Distributor, or write Section S84109, Semiconductor Products Dept., General Electric Company, Electronics Park, Syracuse, New York.

GENERAL ELECTRIC

Semiconductor Products Dept., Syracuse, New York

Circle No. 8 on Reader Service Card

Let KNAPIC *grow your* SILICON CRYSTALS *for you!*

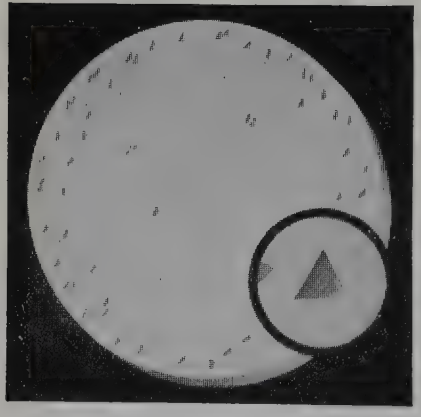
kep

SILICON AND GERMANIUM MONOCRYSTALS

For Semiconductor, Solar Cell and Infrared Devices

Major manufacturers of semiconductor devices have found that Knapic Electro-Physics, Inc. can provide production quantities of highest quality silicon and germanium monocrystals far quicker, more economically, and to much tighter specifications than they can produce themselves. Knapic Electro-Physics has specialized in the custom growing of silicon and germanium monocrystals. We have extensive experience in the growing of new materials to specification. Why not let us grow your crystals too?

Knapic monocrystalline silicon and germanium is available in evaluation and production quantities in all five of the following general grade categories —Zener, solar cell, transistor, diode and rectifier, and high voltage rectifier.



Dislocation density, Knapic silicon monocrystals. Crystal diameter 1/10" to 3/8"—None; 3/8" to 3/4"—less than 10 per sq. cm.; 3/4" to 1-1/4"—less than 100 per sq. cm.; 1-1/2" to 2" less than 1000 per sq. cm.

SPECIFICATIONS – Check These Advantages

- ☐ **Extremely** low dislocation densities.
- ☐ **Tight** horizontal and vertical resistivity tolerances. Resistivities available in controlled ranges .005 to 1000 ohm cm., N and P type.
- ☐ **Diameters** from .10" to 2". Wt. to 250 grams per crystal. Individual crystal lengths to 10".
- ☐ **Low Oxygen content** 1×10^{17} per cc., 1×10^{16} for special Knapic small diameter material.
- ☐ **Doping** subject to customer specification, usually boron for P type, phosphorus for N type.
- ☐ **Lifetimes:** 1 to 15 ohm cm.—over 50 microseconds; 15 to 100 ohm cm.—over 100 microseconds; 100 to 1000 ohm cm.—over 300 microseconds. Special Knapic small diameter material over 1000 microseconds.

Specification Sheets Available

Infrared Domes and Lenses

LARGE DIAMETER SILICON LENSES AND CUT DOMES FOR INFRARED USE.

Individual silicon ingots for lens use and hollow cut domes to 8" diameter are now available in production and evaluation quantities. Diameters up to 19" will be available in the near future. Transmission characteristics—minimum 52%, coated 97% in ranges between 1 to 15 microns.

Quotations will be prepared on request for production orders, for semiconductor materials not falling within the listed categories, or for those requiring additional experimental work.

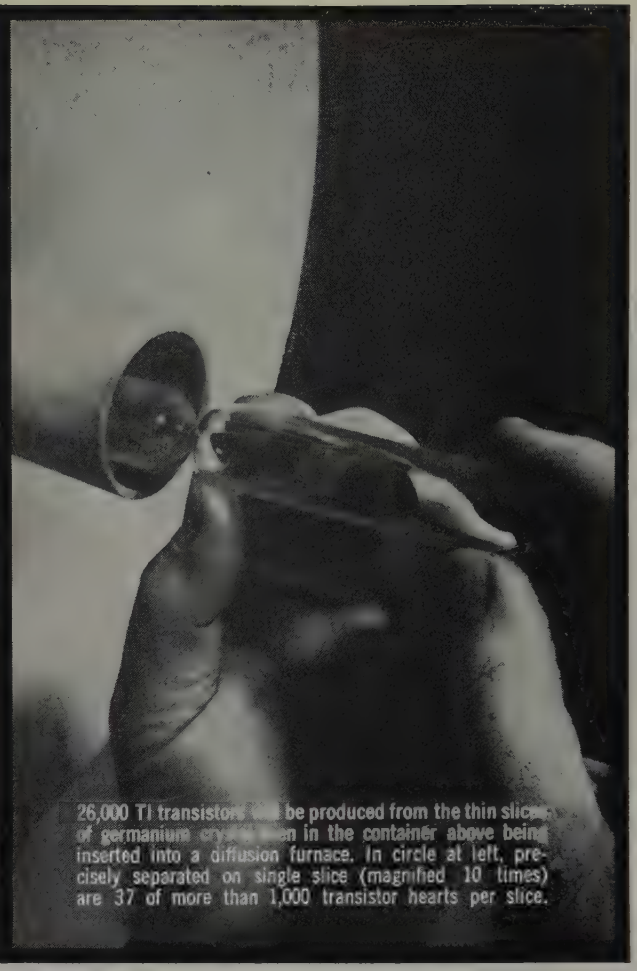
Knapic Electro-Physics, Inc.

936-938 Industrial Avenue, Palo Alto, California Phone: DAvenport 1-5544

Circle No. 9 on Reader Service Card

CAREER OPPORTUNITIES AT TI

DEVICE DEVELOPMENT ENGINEER


26,000 TI transistors can be produced from the thin slices of germanium crystal shown in the container above being inserted into a diffusion furnace. In circle at left, precisely separated on single slice (magnified 10 times) are 37 of more than 1,000 transistor hearts per slice.

your future: a challenging opportunity with an industry leader

Now take advantage of maximum professional growth at Texas Instruments by participating in development of the most advanced semiconductor-component devices. Working with the newest facilities, take part in:

- **DEVICE DEVELOPMENT** Development of new devices by studies in solid-state diffusion, alloying of metals and semiconductors, vacuum deposition of metals, surface chemistry, and solid state physical measurements.
- **SURFACE STUDIES** Surface reactions and surface energy phenomena on silicon and germanium.
- **ADVANCED COMPONENT DESIGN** Development of new components by studies of deposition of thin films, electrolytic studies such as anodic oxidation rates and film structures.
- **NUCLEAR RADIATION** experiments on semiconductor materials and devices.

With TI . . . receive liberal company-paid benefits, including profit sharing *(last year 15% of base salary)* . . . enjoy premium living in a moderate climate with excellent neighborhoods, schools and shopping facilities . . . work in a plant selected as one of the 10 outstanding U. S. industrial buildings of 1958.

Interviews will be held in your area soon. If you have an Electrical Engineering, Physical Chemistry or Physics degree and experience in semiconductor or related development areas, please send a resume to:

C. A. Besio, Dept. 201-SC

For immediate Eastern appointment, contact H. C. Laur Dept. 201-E-SC 1141 E. Jersey St. Elizabeth, N. J.

TEXAS INSTRUMENTS
INCORPORATED
SEMICONDUCTOR – COMPONENTS DIVISION
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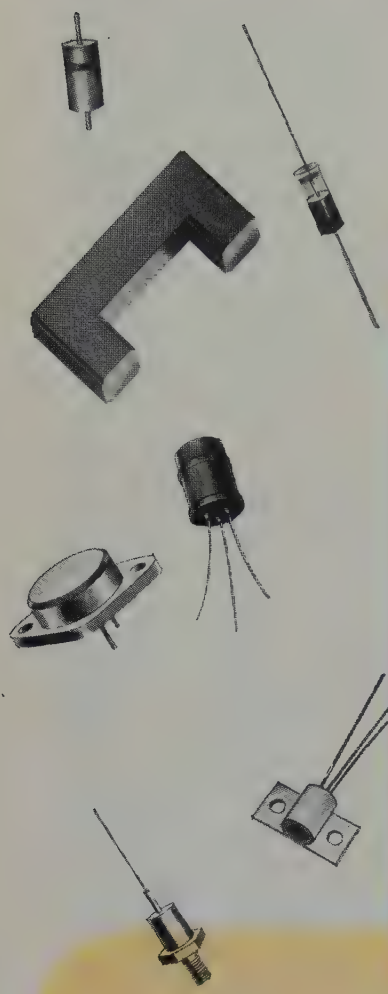
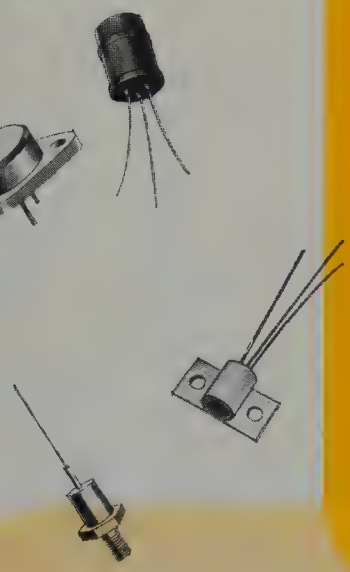
An important message to manufacturers of



semi-conductors
electronic tubes
thermistors
ferrites



J. T. BAKER ELECTRONIC CHEMICALS

Acetic Acid, Glacial
Acetone
Aluminum Nitrate
Aluminum Sulfate
Ammonium Carbonate
Ammonium Chloride
Ammonium Hydroxide
Ammonium Phosphate
Antimony Trioxide
Barium Acetate
Barium Carbonate
Barium Fluoride
Barium Nitrate
Benzene
Boric Acid
Cadmium Chloride
Cadmium Nitrate
Cadmium Sulfate
Calcium Carbonate
Calcium Chloride
Calcium Fluoride
Calcium Nitrate
Calcium Phosphate
Carbon Tetrachloride
Cobalt Carbonate
Cobalt Oxide
Cobalt Nitrate
Ether, Anhydrous
Hydrochloric Acid
Hydrofluoric Acid
Hydrogen Peroxide, 30% and 3% Solution
Lithium Carbonate
Lithium Chloride
Lithium Nitrate
Lithium Sulfate
Magnesium Carbonate
Magnesium Chloride
Magnesium Oxide
Manganese Dioxide
Manganese Nitrate
Manganese Sesquioxide
Manganous Carbonate
Methanol
Nickel Carbonate
Nickel Oxide, Black
Nickel Oxide, Green
Nickelous Chloride
Nickelous Nitrate
Nickelous Sulfate
Nitric Acid
Petroleum Ether
Potassium Dichromate
Potassium Hydroxide
iso-Propyl Alcohol
Radio Mixture No. 3
Silicic Acid
Sodium Carbonate
Sodium Chloride
Sodium Hydroxide
Sodium Phosphate Dibasic
Strontium Carbonate
Strontium Nitrate
Sulfuric Acid
Toluene
Trichloroethylene
Triple Carbonate
Xylene
Zinc Chloride
Zinc Nitrate
Zinc Oxide

You can reduce your production costs with 'Baker Analyzed' Reagents because (1) they are manufactured to exceedingly high standards of purity at no price premium to you, (2) they are consistently pure, consistently uniform, lot after lot, (3) Baker reagent purity regularly offers you the quality-plus demanded by the specialized processes and products of your industry, (4) the regular 'Baker Analyzed' Label defines a degree of purity so high that special "electronic grade" labeling is unnecessary.

As the electronics industry is able to define its needs more precisely, Baker will continue to provide material meeting the required specifications.

Listed at the left are some of the J. T. Baker high purity chemicals of particular importance to electronic manufacturers.

J.T.Ba

CHEMI

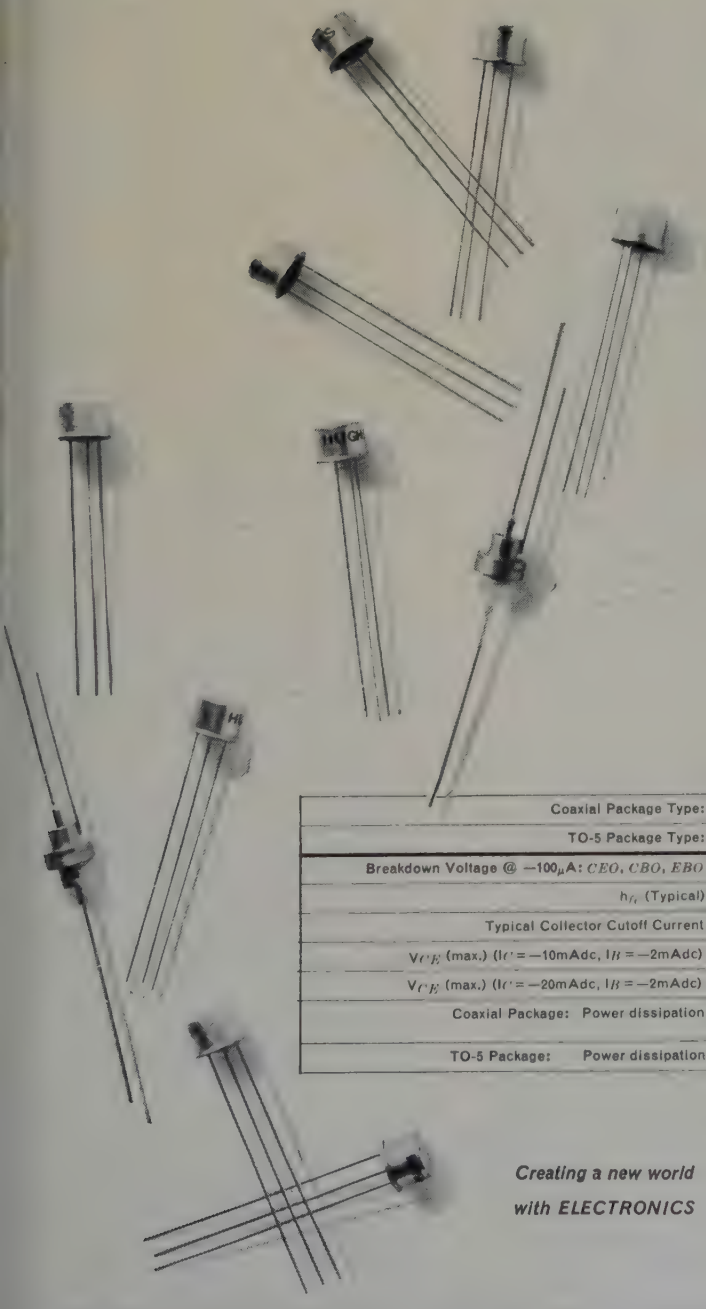
J. T. Baker Chemical Co

Phillipsburg, New Jersey

Circle No. 10 on Reader Service Card

how to get ultra-uniformity

in a Silicon PNP fused alloy transistor



Through precise manufacturing techniques, Hughes PNP fused-junction silicon transistors give you uniformity of parameters by type. Result: Circuit interchangeability no longer is a problem.

Designed for switching and amplifying applications at low and medium current levels, these Hughes transistors offer you a number of advantages:

- **useful Beta over a wide range of collector currents**
- **high punch-thru voltage (BV_{CEO} in excess of 100 volts in types 2N1244 and 2N1234)**
- **low collector cutoff current**

These devices, now available in production quantities, are housed in TO-5 (single ended) and coaxial packages (double ended). Engineered for reliability, they meet MIL-T-19500A specifications.

Your inquiry regarding these transistors will be given prompt attention. Just write Marketing Department, ***HUGHES SEMICONDUCTOR DIVISION, NEWPORT BEACH, CALIFORNIA...*** *or contact the Hughes Semiconductor Sales Office or distributor nearest you.*

Coaxial Package Type:	2N1238	2N1239	2N1240	2N1241	2N1242	2N1243	2N1244
TO-5 Package Type:	2N1228	2N1229	2N1230	2N1231	2N1232	2N1233	2N1234
Breakdown Voltage @ $-100\mu A$: *CEO, CBO, EBO*	−15V	−15V	−35V	−35V	−65V	−65V	−110V
h_{fe} (Typical)	22	40	14	25	14	25	14
Typical Collector Cutoff Current	$-.01\mu Adc$	$-.01\mu Adc$	$-.01\mu Adc$	$-.01\mu Adc$	$-.01\mu Adc$	$-.01\mu Adc$	$-.01\mu Adc$
V_{CE} (max.) (I_C = −10mAdc, I_B = −2mAdc)	−0.2Vdc		−0.2Vdc		−0.2Vdc		−0.2Vdc
V_{CE} (max.) (I_C = −20mAdc, I_B = −2mAdc)		−0.4Vdc		−0.4Vdc		−0.4Vdc	
Coaxial Package: Power dissipation	1 watt in free air (derate 7.4 mw/°C) 5 watts with heat sink (derate 37 mw/°C)				Collector current limited by power dissipation. Operating and storage temperature range −65°C to +160°C		
TO-5 Package: Power dissipation	400 mw (derate 3.0 mw/°C)						

Creating a new world with ELECTRONICS

SEMICONDUCTOR DIVISION

HUGHES PRODUCTS

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SEMICONDUCTOR DEVICES • STORAGE TUBES AND DEVICES • MICROWAVE TUBES • VACUUM TUBES AND COMPONENTS • CRYSTAL FILTERS • MEMO-SCOPE® OSCILLOSCOPES • INDUSTRIAL CONTROL SYSTEMS

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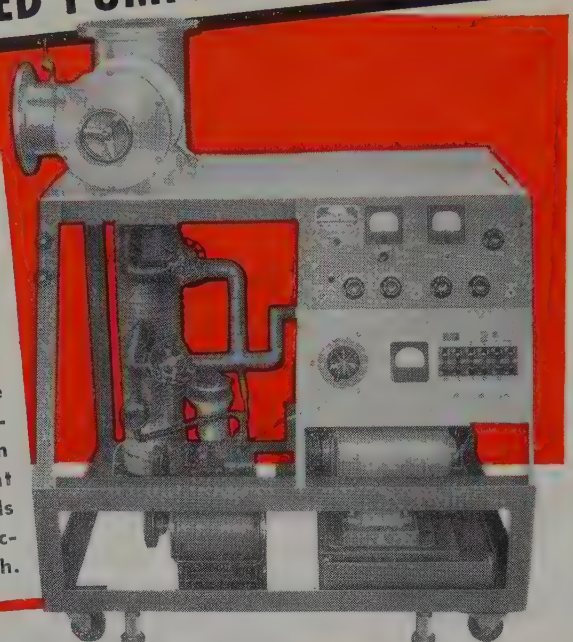
VACUUM

Kinney®

HIGH PERFORMANCE PACKAGED PUMPING SYSTEMS



Built in Models 200, 400 and 600, KINNEY PW Packaged Pumping Systems consist of a KINNEY copper thimble type cold trap, fractionating oil diffusion pump, and two-stage gas ballasted mechanical vacuum pump. High visibility instrument panel with all controls and electrical connections within easy reach.

Get the greater utility and versatility built into these KINNEY PW Series High Vacuum Pumping Systems which users call "the workhorse of the modern laboratory." These units will evacuate altitude chambers, tanks, furnaces, ovens, tubes, bell jars or other laboratory equipment, attaining pressures in the order of 5 x 10^{-6} mm Hg without coolant in the cold trap and substantially lower when coolant is used. These units are mounted on casters so that they can be moved readily to serve a variety of facilities, especially those which are fixed installations. A unique and exclusive High Vacuum Valve design enables the operator to rotate the Valve and position the suction connection horizontally, vertically, or at any angle in between. Thus, it is possible with a base plate assembly to quickly convert to an Evaporator.

Bulletin 4000.1 fully describing the KINNEY PW Packaged Pumping Systems is yours FREE. Mail the coupon today.

Bring your file of new developments in High Vacuum up-to-date. Write today.

KINNEY MFG. DIVISION
THE NEW YORK AIR BRAKE COMPANY
3524K WASHINGTON STREET • BOSTON 30 • MASS

Please send me Bulletin 4000.1 ☐ I am also interested in Mechanical Pumps ☐ Oil Diffusion Pumps ☐ Vacuum Furnaces ☐ Evaporators ☐

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City_____ Zone____ State_____

Circle No. 12 on Reader Service Card

New Literature

A new brochure describing Raytheon's welded assembly technique for high density packaging of electronic components is now available. It details the savings in space, weight, and power consumption made possible with welded assemblies and shows how their high reliability and mechanical ruggedness make them particularly adaptable to installations in data processing equipment, computers, and airborne electronic systems.

Circle 150 on Reader Service Card

A new eight-page general brochure, "Platinum-Group Metals," briefly describes the platinum-metal products of Metals & Controls Division, Texas Instruments Incorporated, including solid and clad platinum metals and alloys in sheet, strip, wire, foil and seamless tubing, parts, shapes and specialties; dental foil, electrical contacts, electrodes, gauze, catalysts, salts and derivitives, expanded anodes, laboratory ware, rhodium plating solutions, transistor materials and thermocouple wire.

Circle 151 on Reader Service Card

A scientific 44 page book, published by Hofman Laboratories, Inc. discusses developments in low temperature chemistry, solid state physics, superconductivity, metallurgical research, maser research, microwave spectrometry, etc. Hofman manufactures liquid helium research dewars and related apparatus for cryogenics, and the book relates the application of this equipment in various fields of low temperature studies.

Circle 152 on Reader Service Card

A new brochure, "Better Chemical Milling Through Research" is available from Chemical Milling International Corporation. The brochure describes the new company's services, which include: research, consultation, and production of chemically-milled parts.

Circle 153 on Reader Service Card

A new Markem catalog describes practical methods and equipment for clear, fast marking of all types of electrical and electronic products. A product index, ranging from wire lead components to panels and chassis, guides the manufacturer to the best marking method for his product; marking curved, flat or irregular surfaces; production runs with infrequent changes of marking, or short runs with frequent imprint changes. Special sections also describe machines for Underwriters' Laboratories manifest label legend marking, etc.

Circle 154 on Reader Service Card

Two-color catalog sheet offers detailed technical data on Arnold Magnetics Model 851H transistorized power supply. The text describes an added circuit in the model which has the effect of rendering the power supply non-operative when the input polarity is inadvertently reversed. Also included are dimensional drawings and complete specifications and ordering information.

Circle 155 on Reader Service Card

A revised catalog that describes and illustrates the CDF line of Micabond bonded mica insulation is available from Continental-Diamond Fibre Corp. Sixteen pages in length and printed in two colors, it offers more complete information about properties, tolerances and composition of various grades than was prveiously available. It also includes complete information on four new grades of this material. Titled "CDF Micabond," this catalog lists complete information about grades, forms, sizes, weights and specifications for this insulating material.

Circle 156 on Reader Service Card

A newly published booklet, entitled, "Tips on Ultrasonic Cleaning," is being offered by Circo Ultrasonic Corporation. The 12-page booklet includes a simplified explanation of the basic principles of ultrasonics, a brief description of the generating equipment and transducers required for ultrasonic cleaning, a discussion of proven applications, and a list of seventeen of the most frequently asked questions about ultrasonics, with appropriate answers.

Circle 157 on Reader Service Card

An applications bulletin describing the technique for cleaning miniature differentials ultrasonically has been released by Acoustica Associates, Inc., manufacturer of ultrasonic systems. The bulletin describes how assembled units, designed for use in precision electromechanical equipment, can be completely cleaned in less than one minute without disassembly. The current bulletin is one of a series designed to acquaint prospective and current users of ultrasonic cleaning equipment with the most efficient cleaning techniques. It is entitled "Cleaning Miniature Differentials."

Circle 158 on Reader Service Card

A 250-page electronic designers reference manual devoted exclusively to shock and vibration environments has been published by Wright Air Development Center (WADC), Dayton, Ohio, for use by electronic contractors engaged in work for the Air Research and Development Command (ARDC). It is entitled, "Electronic Designers Shock and Vibration Guide For Airborne Application." Technicians and scientists from the WADC Electronic Components Laboratory worked with RCA electronic engineers to complete the document.

Circle 159 on Reader Service Card

The many design features of the Type LAC-50M conveyor heat treating furnace for alloying transistors and diodes, are described in a new bulletin just issued by C. I. Hayes, Inc., developers and manufacturers of electric furnaces. Interim Bulletin 5711B gives complete design specifications, describes the various components and control equipment, and shows heat control curves.

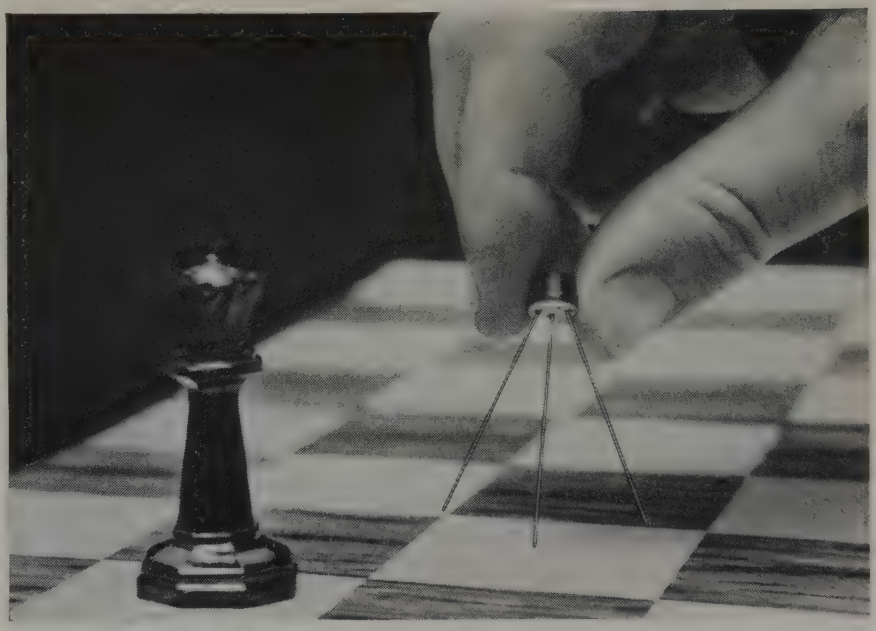
Circle 160 on Reader Service Card

"Symbolic Logic, Boolean Algebra And The Design Of Digital Systems," by the Technical Staff of Computer Control Company, Inc., is a 36-page, two-color booklet which presents in a clear and understandable form the fundamentals of Symbolic Logic as applied to the logical design of digital systems. It is the intention of this booklet to make this knowledge available in a single coherent presentation so that others in the industry may benefit similarly.

Circle 161 on Reader Service Card

BENDIX TRANSISTOR VERSATILITY

POWER SUPPLY • AUDIO AMPLIFIER (CLASS A OR B) • AUDIO OSCILLATOR • POWER SWITCH • TRANSISTOR DRIVER • SERVO CONTROL • RELAY DRIVER • MOTOR CONTROL



CHECKMATE HIGH COSTS AND DESIGN LIMITATIONS

The new Bendix™ "yeoman" driver transistor series is engineered to perform over a wide range of audio frequency applications. The new 2N1176 series will find broad use wherever reliability, versatility and low cost are primary design requirements.

Each of the three "yeoman" models, 2N1176, 2N1176A and 2N1176B, has a different voltage rating, but all are contained in a rugged, welded JEDEC TO-9 package. Dissipation ratings are 300 mW at 25°C and 50 mW at 75°C. Higher voltage rating and high current gain coupled with a more linear current gain curve yield low distortion and efficient switching. Saturation resistance is very low—typical values are 1 ohm measured at 100 mAdc.

Write today for the new Bendix Semiconductor Catalog for more information on our complete line of power transistors, power rectifiers and driver transistors. SEMICONDUCTOR PRODUCTS, BENDIX AVIATION CORPORATION, LONG BRANCH, N. J.

	MAXIMUM RATINGS				TYPICAL OPERATION	
	Vce Vdc	Ic mAdc	Pc mW	Tj °C	Current Gain hFE at Ic	
2N1176	15	300	300	85	50	10 mAdc
2N1176A	40	300	300	85	50	10
2N1176B	60	300	300	85	50	10

West Coast Sales Office: 117 E. Providencia Avenue, Burbank, California
Midwest Sales Office: 4104 N. Harlem Avenue, Chicago 34, Illinois
New England Sales Office: 4 Lloyd Road, Tewksbury, Massachusetts
Export Sales Office: Bendix International Division, 205 E. 42nd Street, New York 17, New York
Canadian Affiliate: Computing Devices of Canada, Ltd., P.O. Box 508, Ottawa 4, Ontario, Canada

Red Bank Division — Bendix AVIATION CORPORATION

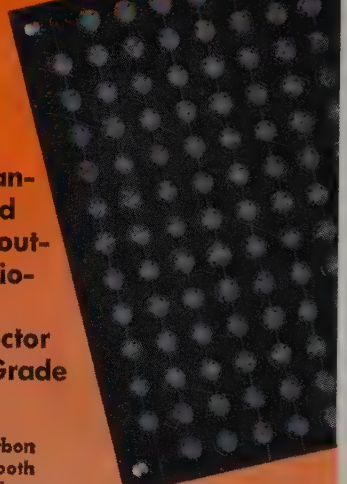
Circle No. 13 on Reader Service Card

PURE CARBON

HI-PURITY... HARD-DENSE CARBON and GRAPHITE for

1. GLASSING BOATS
2. ALLOYING BOATS
3. CRUCIBLES
4. EMITTER and COLLECTOR WASHERS

- *PROVIDES OUTSTANDING OVEN LIFE*
- *RESISTS OXIDATION AND MECHANICAL EROSION*



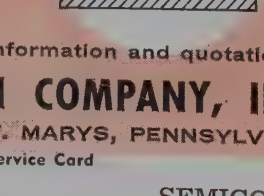
The Pure Carbon Company has complete facilities for the precision manufacturing of all types of boats and fixtures in *Grade L-56 and other outstanding materials. We have also pioneered the manufacture of small, extremely accurate emitter and collector washers, header weights, etc., in **Grade P-1.

*The most widely used electro-graphite in the semi-conductor industry

**Molded-to-size carbon graphite with dense, smooth surfaces and chip-free edges

EMITTER and COLLECTOR WASHERS

Sectional view of typical configuration shown 20X size



Write for complete information and quotations

PURE CARBON COMPANY, INC.

449 HALL AVE. ST. MARYS, PENNSYLVANIA

Circle No. 14 on Reader Service Card

A new 16 page catalog 9-169, issued by the Mallory Capacitor Company contains complete information on the fifteen different types of solid, foil and sintered anode tantalum capacitors manufactured by the company. Types range from high temperature tantalum capacitors for 200°C operation to subminiature capacitors hardly larger than a pin. A feature of the catalog is a table containing over 600 listings arranged by microfarad and voltage ratings. The list extends from .2 to 1300 mfd.

Circle 167 on Reader Service Card

A 16-page product summary and price list that classifies vacuum equipment and components by type and code number is now available from NRC Equipment Corporation. Over 600 listings covering pumps, valves, gauges, seals, furnaces, analytical equipment, coaters, leak detectors, freeze-dehydration units, high altitude test facilities, and many other types of equipment, accessories, and supplies are grouped under various sub-headings that are arranged for easy reference. Special or single-design equipment has, of necessity, been omitted, however, such information is available on request. Also, the user can readily select individual components from the listings for high vacuum systems of his own design.

Circle 168 on Reader Serivce Card

A new technical brochure published by Technitrol Engineering Company illustrates and describes its standard line of distributed constant delay lines and pulse test equipment. The brochure lists all electrical specifications on the 25E, 25F, 25G and 25J Series delay lines such as impedance, delay, rise time, attenuation, and test voltage, and includes environmental characteristics. Also illustrated with physical dimensions are the various case styles available which include metal cans, epoxy sticks and dip coated units. Prices are given for all delay lines carried as stock items in quantities from 1 to 99.

Circle 169 on Reader Service Card

Sprague Electric Company has issued Engineering Bulletin No. 2063A on their Type 148P and 149P Yellow-Jacket Film-ite 'E' Capacitors for entertainment and commercial electronics. Bulletin gives standard ratings, lists performance characteristics and shows electrical versus temperature characteristics of these capacitors.

Circle 163 on Reader Service Card

A new eight page, illustrated brochure describing the field service capabilities of Hoffman Electronics Corporation's Laboratories Division is now available. The booklet outlines the field services Hoffman offers on a world-wide basis in the areas of field engineering, overhaul and repair, test equipment, standards, training and medical electronics.

Circle 172 on Reader Service Card

Publication of a data sheet on new, smaller, Style 20 Silicon Power Rectifiers, designed for operation at current levels from one to fifteen amperes (single phase half wave average) is announced by Syntron Company. Illustrated sheet presents complete description, data and specifications for new rectifiers.

Circle 173 on Reader Service Card

A new edition, the fourth, of the Transistor Manual has been published by the General Electric Company, and is available for a nominal charge. The new book contains 227-pages of completely re-written information on transistors and their use in electronic circuits. Included in the twenty chapters is information on basic semiconductor theory, transistor construction techniques, biasing, switching characteristics, transistor radio servicing techniques and several chapters on circuits.

Circle 175 on Reader Service Card

The latest issue of the C.I.C. Newsletter has a feature article on ultrasonic machining covering the basic principles of ultrasonic machining, the operations that can be carried out and the materials that can be machined. Another article discusses the use of glass in back-lighted aviation instruments, giving helpful suggestions to designers working on integral instrument lighting.

Circle 176 on Reader Service Card

Electronic Research Associates, Inc., announces the availability of a new two-color catalog sheet #118 describing their new line of solid state, miniaturized, high amperage power packs. The catalog sheet provides descriptive information on the full line of battery voltage output units, specifications, model types and prices.

Circle 177 on Reader Service Card

Revised and expanded to 40 pages, new edition of Booklet SCD-108B contains technical data on RCA germanium and silicon transistors, and silicon rectifiers. Maximum ratings, typical operation, characteristics, and dimensional outline are given for each type. Also included are a section on transistor theory, an interchangeability directory which lists over 1100 type designations of 29 different manufacturers, and a section on circuits containing 37 schematic diagrams illustrating some of the more important applications of transistors and silicon rectifiers. Available at small charge.

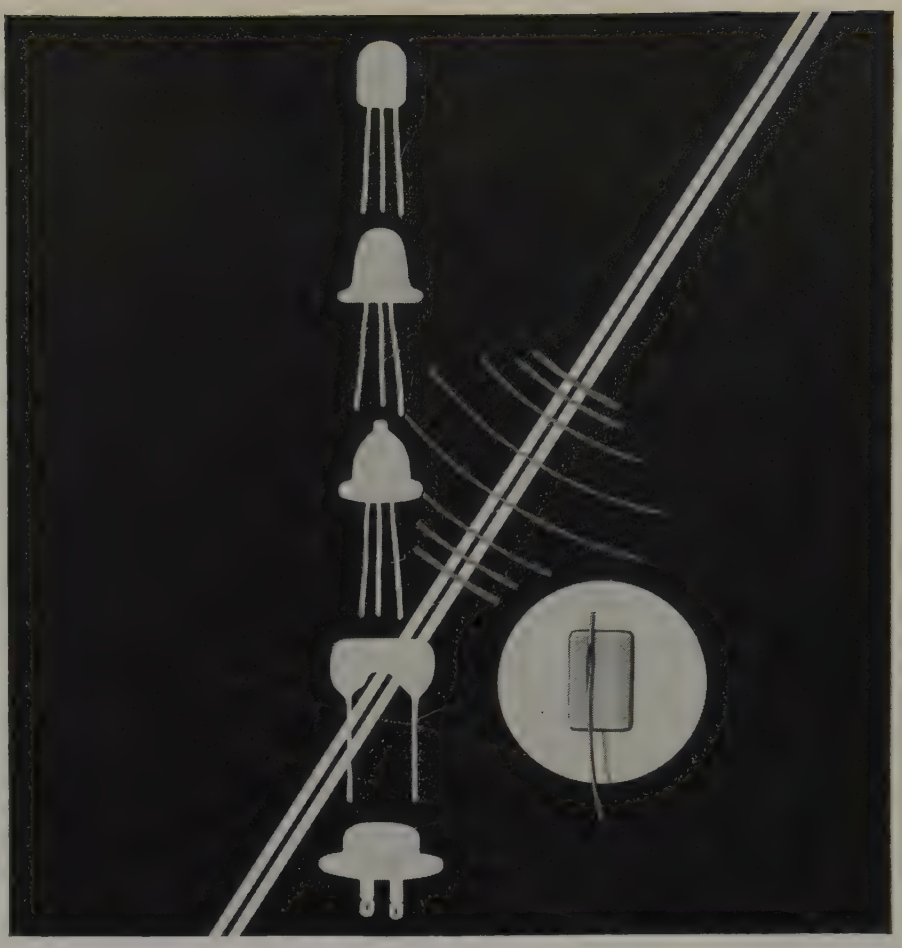
Circle 174 on Reader Service Card

The physical properties of lead-antimony, tin-antimony, tin-gold and other semiconductor alloys are described in a series of technical data sheets prepared by Alpha Metals, Inc. Each of these "Semiconductor Materials Data Sheets" contains a phase diagram of a particular alloy combination as well as a thorough description of the phase relationship and crystal structure, alloy properties and fabrication possibilities of those alloys. The data sheets come in a handy file folder and are specially punched to fit a variety of binder styles.

Circle 171 on Reader Service Card

A new "Concise Compendium" or, more commonly referred to as a Short Form Catalogue, is now available from Emerson & Cuming, Inc. This contains a condensed listing of this company's complete line of dielectric materials, including casting resins, foams, absorbers, adhesives, impregnants, coatings, ceramics and reflectors. It is in color and pictures many of the uses of their varied products. Centered in the catalogue is a chart giving data on the various standard resins of the company.

Circle 166 on Reader Service Card



INCREASES PRODUCTION YIELD IN SEMICONDUCTOR ASSEMBLY

100-watt SONOWELD unit, Model W-100-TSL-58-6 designed specifically for welding small semiconductor components. Generator size, 22x14x15 inches.

The photographic enlargement shows .005" aluminum wire welded ultrasonically to silicon wafer with SONOWELD, the precision ultrasonic welding tool.

With SONOWELD, you get low ohmic contact, no penetration. Readily adapted to automation in semiconductor assembly. High reproducibility is achieved in joining aluminum or gold leads to silicon or germanium. Contamination is eliminated. There is no arc, spark, or sputter. Current does not pass through the weld.

For reliable welds with high production yield, investigate SONOWELD today.

SONOBOND CORPORATION
West Chester, Pa. Telephone: OWen 6-4710
A Subsidiary of Aeroprojects Incorporated

Get Bulletin 118 for further information on ultrasonic welding. See the wide range of applications with various size SONOWELD units. No obligation, naturally.

SONOWELD®

Circle No. 15 on Reader Service Card

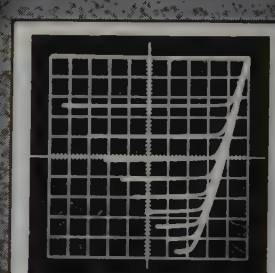
Tektronix Transistor Curve Tracer

Displays 4-12 curves per family

20-Ampere Collector Displays

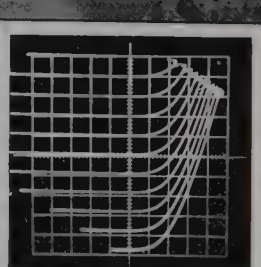
(10-ampere average supply current)

2.4-Ampere Base Supply



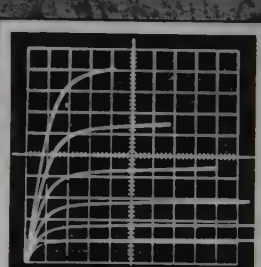
HIGH COLLECTOR CURRENT

PNP transistor, collector current vs collector voltage with constant-current base steps. Collector sweep is 0 to 5 v with a 0.25-ohm load, base current is 50 ma/step. Vertical deflection is 1000 ma/div, horizontal 0.5 v/div.



HIGH INPUT CURRENT

PNP transistor, collector current vs collector voltage with base grounded and constant-current emitter steps. Collector sweep is 0 to 1.5 v, emitter current 200 ma/step. Vertical deflection is 200 ma/div, horizontal 0.1 v/div. Zero voltage is at center scale.



LOW INPUT CURRENT

NPN transistor, collector current vs collector voltage with constant-current base steps. Collector sweep is 0 to 1.5 v, base current 1 microamp/step. Vertical deflection is 10 microamp/div, horizontal 0.1 v/div.

Input current from 1 MICROAMP/STEP to 200 MILLIAMPS/STEP

TYPE 575 CHARACTERISTICS

Positive or Negative Collector Sweep

Collector supply—0 to 20 v, 10 amperes average current.
—0 to 200 v, 1 ampere average current.
Dissipation limiting resistors—0 to 100-kilohms in 17 steps.

Positive or Negative Base Stepping

4 to 12 steps per family, repetitive or single family display.
17 current-per-step positions, 1 μa/step to 200 ma/step.
5 voltage-per-step positions, 0.01 v/step to 0.2 v/step, with 24 series resistance values from 1 ohm to 22 kilohms.

Calibrated Display

Vertical axis—
Collector current, 16 steps from 0.01 ma/div to 1000 ma/div.
Pushbuttons are provided for multiplying each current step by 2 and dividing by 10, increasing the current range to 0.001 to 2000 ma/div.
Horizontal axis—
Collector volts, 11 steps from 0.01 v/div to 20 v/div.
Both axes—
Base volts, 6 steps from 0.01 v/div to 0.5 v/div.
Base current, 17 steps from 0.001 ma/div to 200 ma/div.
Base source volts, 5 steps from 0.01 v/div to 0.2 v/div.

Test Condition Selector

Select either common-emitter or common-base configuration.

Price $975 **f.o.b. factory**

Tektronix, Inc.

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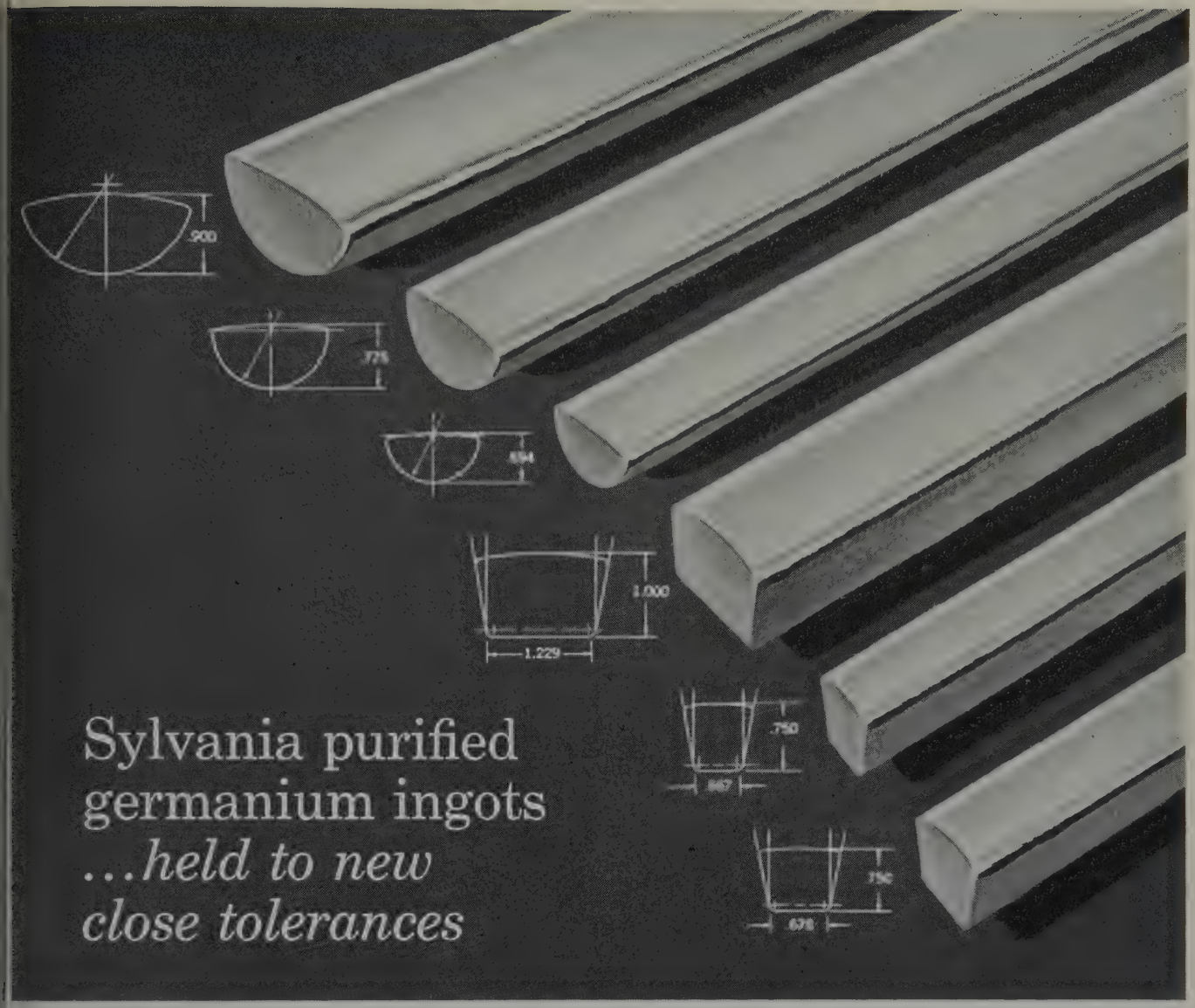
TEKTRONIX ENGINEERING REPRESENTATIVES: Hawthorne Electronics, Portland, Oregon, Seattle, Wash.; Hytronic Measurements, Denver, Colo., Salt Lake City, Utah.

Tektronix is represented in 20 overseas countries by qualified engineering organizations.

Circle No. 16 on Reader Service Card



Sylvania purified germanium ingots ...held to new close tolerances

...new dimensions for precise crystal growing

Sylvania germanium pieces, cut to specific size and weight for vertical crystal growing.

THROUGH THE YEARS, from early experimental projects to the place Sylvania now occupies as prime suppliers of as-reduced and purified germanium . . . Sylvania has constantly worked to provide ingots with the maximum yield potentials in single crystals.

Sylvania is now equipped to supply germanium ingots to the closest dimension-tolerances ever achieved. Shown here are the six standard shapes which fill practically every requirement. In each case, the dimensions are held to a new order of precision.

These new precise dimensions result in even melting, less shrinkage and almost negligible surface drop . . . all important factors in preventing waste through polycrystalline formation. You'll find that the unit cost of doped single crystals is lower too.

Special shapes of ingots can of course be supplied to your order if required, and users of the vertical growing method will like Sylvania germanium cut to specific size and weight. These pieces can be used as received, without processing.

Since Sylvania controls germanium purity from ore to ingot, you can't obtain better material. We'll be glad to send you a new technical bulletin on Sylvania germanium ingot dimensions, showing the new sizes, shapes and tolerances.

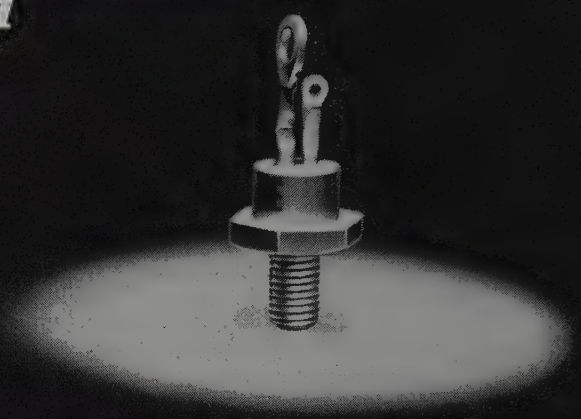
SYLVANIA
Subsidiary of
GENERAL TELEPHONE & ELECTRONICS

Sylvania Electric Products Inc.
Chemical & Metallurgical Div.
Towanda, Penna.

Circle No. 17 on Reader Service Card

ENGINEERS AND SCIENTISTS:

Join us in developing the revolutionary controlled rectifier



The remarkable new semiconductor shown above combines features of a transistor and a rectifier: It not only changes AC to DC, but also controls current "on" and "off".

General Electric's silicon controlled rectifier thus offers the circuit designer complete control of current turn-on without complicated circuitry—plus switching speeds in microseconds. Already it is causing fundamental changes in the electrical and electronic industries.

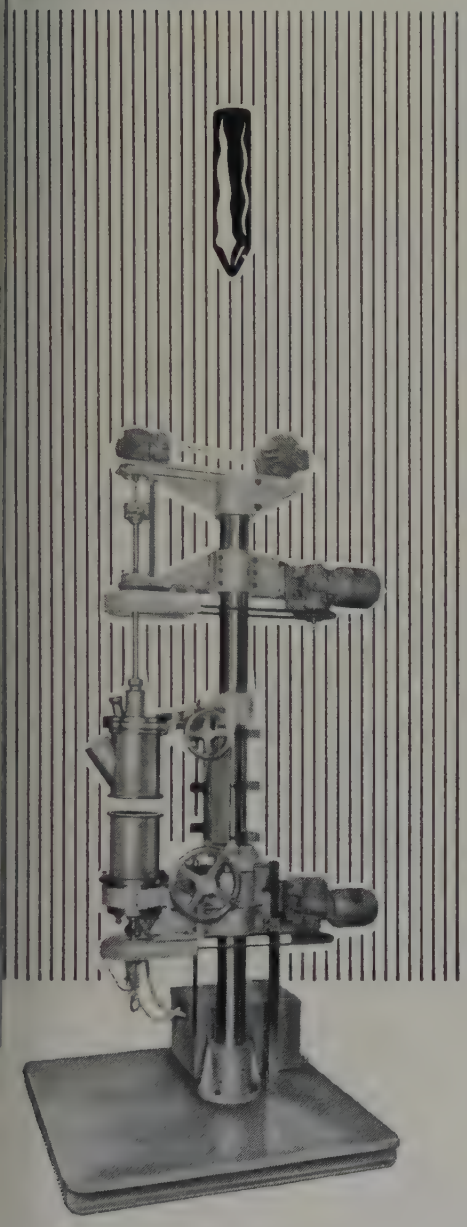
This is typical of the dramatic projects you will be working on at G-E Semiconductors. We now have unusual opportunities for chemical, electrical, mechanical and metallurgical engineers, physicists and physical chemists (B.S. through Ph.D.) at all levels of experience. U. S. Citizenship is not required. Semiconductor experience is desirable but not essential.

Assignments are in the fields of semiconductor applied research, device design and process development, semiconductor materials engineering, test and production equipment design and development, application engineering, and quality control. You'll live in the heart of New York's famous Vacationland adjacent to the famed Finger Lakes region, the Thousand Islands, and the Adirondack Mountains. Liberal benefits include tuition refund for graduate studies at Syracuse University. Write in strict confidence to Mr. M. D. Chilcote, Division F.

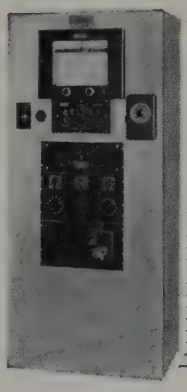
GENERAL ELECTRIC

Semiconductor Products Department, Electronics Park, Syracuse, New York

THE BEST SEMI-CONDUCTORS MADE....



ARE MADE ON KÄHLE MACHINES



KAHLE CRYSTAL GROWING MACHINES . . . featuring a single unit for temperature, timing, programming, and motor control...set new high-precision standards in the production of single billets of Germanium, Silicon, or related semiconductor crystals. Designed to function efficiently and economically with either RF or resistance-type heating systems, each machine is pre-tested . . . under actual operating conditions . . . prior to shipment.

This machine is just one example of the full line of fine Kahle equipment for the production of semiconductors and electron tubes.

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KÄHLE
ENGINEERING COMPANY

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LEADING DESIGNERS AND BUILDERS OF MACHINERY FOR THE ELECTRONIC INDUSTRY

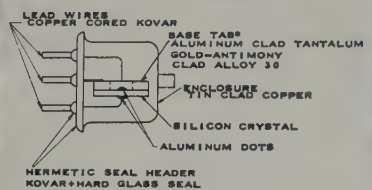
Circle No. 18 on Reader Service Card

General Plate Clad Metals

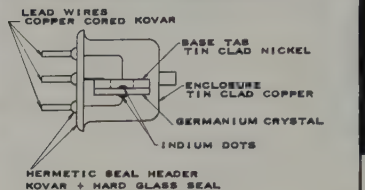
IMPROVE PERFORMANCE – CUT COSTS

In Semiconductor Applications

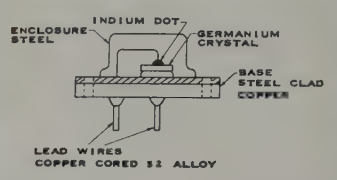
SILICON TRANSISTOR

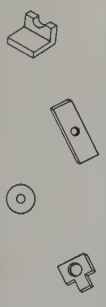


GERMANIUM TRANSISTOR



GERMANIUM POWER TRANSISTOR





I BASE TAB MATERIAL

A For Germanium (Single Clad Only)

1. Tin Clad Nickel
2. Tin Clad Alloy 30 (42% Nickel-58% Iron)
3. 63.2% Lead-35% Tin-1.8% Antimony Clad Nickel
4. 63.2% Lead-35% Tin-1.8% Antimony Clad Alloy 30
5. 63.2% Lead-35% Tin-1.8% Indium Clad Nickel
6. 63.2% Lead-35% Tin-1.8% Indium Clad Alloy 30
7. 99% Tin-1% Gallium Clad Nickel
8. 98% Tin-2% Antimony Clad Nickel
9. 95% Tin-5% Antimony Clad Nickel
10. Tin Clad Steel
11. Tin Stripe on Nickel
12. Tin Clad Titanium

B For Silicon (Single or Double Clad & Stripes)

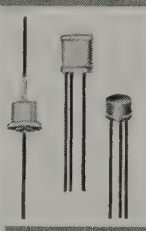
**Solder

1. Gold
2. 99.5% Gold-.5% Antimony
3. 99% Gold-1% Gallium
4. 95% Gold-5% Indium
5. 99.9% Gold-.1% Boron
6. 99% Gold-1% Aluminum
7. 99% Gold-1% Arsenic
8. Fine Silver
9. 99.5% Silver-.5% Antimony
10. 95% Silver-5% Indium
11. Aluminum
12. High Purity Aluminum

BASE METAL

1. Nickel
2. Alloy 20 (40% Nickel-60% Iron)
3. Alloy 30 (42% Nickel-58% Iron)
4. Kovar
5. Titanium
6. Tantalum
7. Molybdenum
8. Silver
9. Platinum

**NOTE: These solders may be single or double clad on any of the base metals listed above. Solders in group B may be purchased unclad.



II LEAD WIRE MATERIAL

1. Copper Cored Rodar (Soft Glass Seals)
2. Copper Cored 52 Alloy (Compression Seals)
3. Copper Cored 446 Stainless Steel
4. Nickel Clad Copper Wire
5. Copper Clad Nickel Wire

III WHISKER WIRE MATERIAL

1. 95% Platinum-5% Ruthenium
2. 99% Gold-1% Gallium
3. 99.5% Gold-.5% Antimony
4. 90% Platinum-10% Iridium

IV BASE MATERIAL

1. Aluminum Killed Low Carbon Steel Clad Copper
2. Stainless Steel Clad Copper
3. Nickel Clad Steel (Nifer)®
4. Nickel Clad Copper
5. Nickel Clad Tantalum
6. Silver Clad Tantalum
7. Aluminum & Nickel Double Clad Tantalum

V ENCLOSURE MATERIAL

1. Tin Clad Copper
2. Glass Clad Nickel Silver
3. Tantalum Clad Nickel Silver

If you are seeking metals with useful characteristics that can't be found in a single metal or alloy, investigate clad metals. General Plate Clad Metals do what other metals can't. Made by metallurgically bonding single metals or alloys to other metals in the solid state by exclusive processes*, the composite metals give you the *combined* advantages of the selected metals and can *yield new advantages* such as lower cost, better fabricating qualities, improved parts performance, etc.

The General Plate Clad Metals for semiconductor applications described here comprise only a partial listing. To find out more about these or other combinations to meet your specific requirements, write directly to Industrial Metals Product Manager, or request our special catalog on clad and solid metals for electronics applications.

*Patented processes of Metals & Controls Corporation.

METALS & CONTROLS

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A DIVISION OF TEXAS INSTRUMENTS INCORPORATED

GENERAL PLATE PRODUCTS: Clad Metals • Electrical Contacts • Truflex® Thermostat Metal • Platinum Metals • Reactor Metals • Radio Tube & Transistor Metals

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FROM GENERAL INSTRUMENT CORPORATION

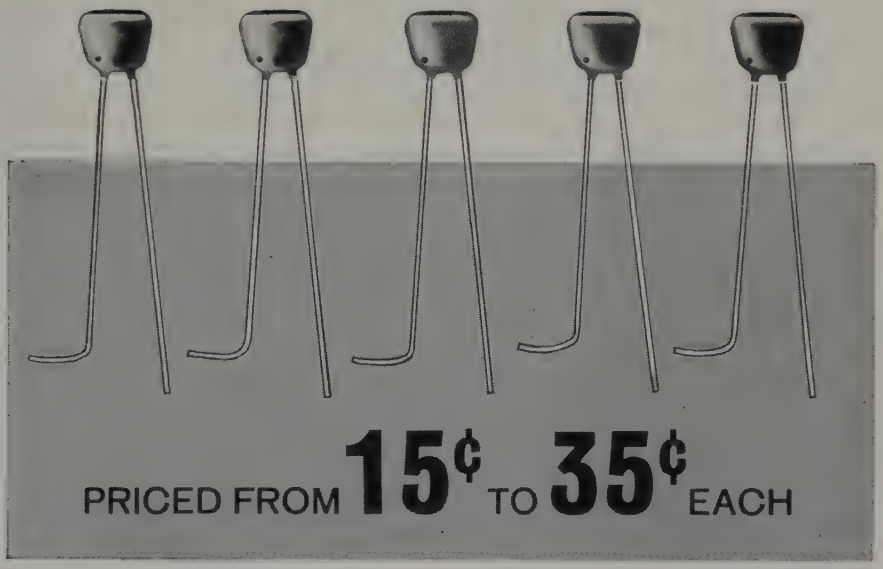
NOW...

HIGH RELIABILITY FOR PENNIES!

REALLY RR RELIABLE

RADIO RECEPTOR

SELENIUM DIODES



PRICED FROM **15¢** TO **35¢** EACH

small size... μa leakage

TYPICAL UNITS	1XH — Half wave — 50 PIV, 12.5 Ma
	2XH — Half wave — 100 PIV, 12.5 Ma
	4XH — Half wave — 200 PIV, 12.5 Ma
	5XH — Half wave — 250 PIV, 12.5 Ma
	8XH — Half wave — 400 PIV, 12.5 Ma

Also available as doubler, center tap, 4-way bridge and special circuits.

For complete information, write today to Section SP-3

RR RADIO RECEPTOR AUTOMATIC

GI

RADIO RECEPTOR COMPANY, INC.
Subsidiary of General Instrument Corporation
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General Instrument Corporation includes F. W. Sickles Division, Automatic Manufacturing Division, Radio Receptor Co., Inc., Micamold Electronics Manufacturing Corporation and Harris Transducer Corporation (Subsidiaries)

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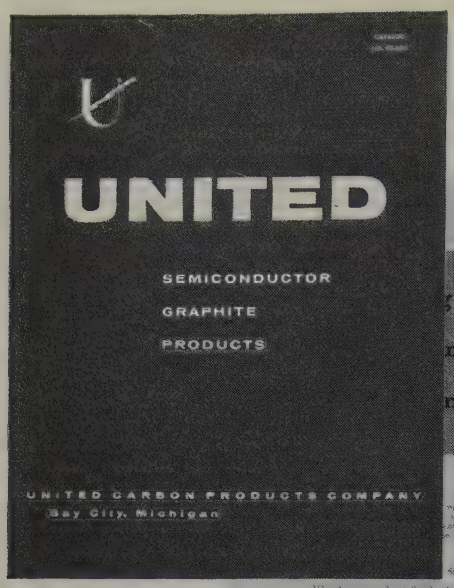

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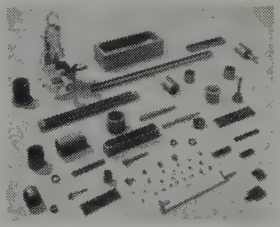

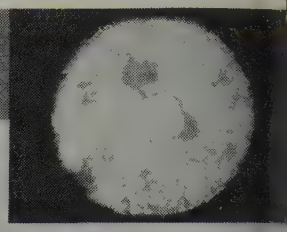

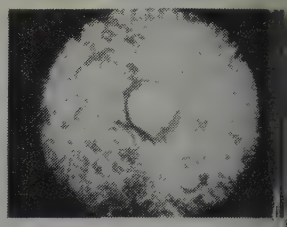

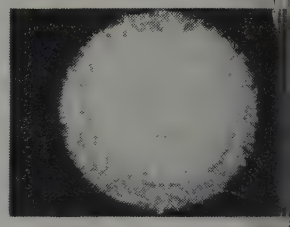

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Frequency Multiplication And Division By Semiconductor Diodes At Microwave Frequencies*

D. LEENOV and A. UHLIR, JR.**

Semiconductor diodes offer unique advantages as harmonic generators, because of their small size and low power requirements. These devices may be used to generate significant amounts of power at microwave and even millimeter wave frequencies. In this paper a new semiconductor device, the *p-n* junction nonlinear capacitor diode, is described. A theoretical discussion is included to show that this device should be a considerably more efficient harmonic generator than the point-contact diode, a semiconductor device of long standing. Examples of harmonic generation yields obtained with nonlinear capacitance diodes are given to illustrate the superiority of these devices.

[Tear sheets of this article are available on written request]

THE HARMONIC GENERATOR is familiar as a means of generating power at frequencies for which other power sources are not readily available. A semiconductor diode harmonic generator is desirable because of its small size and low power requirements. Such a device makes possible the construction of an all-solid-state generator of microwaves, consisting of a high frequency diffused base transistor plus a diode operating as a harmonic generator. The harmonic generator might also be an effective generator of millimeter waves, used, for example, to supply local oscillator power for a superheterodyne detector. Further, in connection with a crystal stabilized oscillator, a harmonic generator will furnish a standard frequency in the microwave region.

Semiconductor diodes operating as harmonic generators have in fact been known for some time. In the 1940's, point-contact crystal rectifiers and welded-contact diodes were investigated for this application.[1] Diodes of the latter type were generally found to be better harmonic generators, and were particularly superior in generating the third harmonic from a fundamental at 1.2 cm. These results suggested that a significant improvement in the harmonic generation performance of diodes might be obtained by appropriate choice of design.

It is well known that nonlinear circuit elements generate harmonics. Our attention here will first be directed to a theoretical discussion of two ideal types of nonlinear elements, the nonlinear resistor and the nonlinear capacitor. Semiconductor diodes may approximate one or the other of these types. It will be shown that the nonlinear capacitor is the superior harmonic generator, and that it can also generate subharmonics. We shall then describe the construction of nonlinear capacitor type diodes. Finally, we shall quote some representative experimental results obtained with these diodes.

The nonlinear resistor, mentioned above, is exemplified by the point-contact crystal rectifier. Its action as a frequency mixer and harmonic generator depends upon its nonlinear voltage-current characteristic. The nonlinear capacitor is a charge storage device which has a nonlinear relation between charge and voltage. The resistive component of its impedance should be made as small as possible, in order to have a high Q.

As one way of comparing these two kinds of devices, we shall analyze their performances in a broadband harmonic generator circuit; that is, one with resistive termination at all frequencies. It will be assumed that the devices are ideal. For the nonlinear resistor this means zero conductance for reverse voltages, and infinite conductance at forward voltages. The ideal nonlinear capacitance has zero capacitance at reverse voltages, and infinite capacitance at forward voltages. These are fairly accurate approximations, respectively, of the behavior of the point-contact rectifier and of the *p-n* junction diode described below, when they are driven by alternating voltages of large amplitude. The following calculations thus apply in the limit of large applied power. At low power, the non-linearities of these devices are small, and the harmonic powers, P_n, are very small, being given by $P_n \propto (P_1)^n$, where P_1 is the fundamental frequency power.

Harmonic Generation with Nonlinear Resistor

Consider first the nonlinear resistor in the broadband circuit. When an alternating voltage is applied,

*Based in part on investigations supported by the U.S. Army Signal Corps on contract DA 36-039 SC-73224.

**The material presented in this article is the result of work done by the authors at the Bell Telephone Laboratories Inc., Murray Hill, N.J. Mr. Leenov is still associated with the Bell Laboratories. Mr. Uhlir is now with Microwave Associates, Burlington, Mass.

the reverse current is zero, and the forward current is limited by the constant resistance in the rest of the circuit. The current *vs.* time curve thus looks like the usual half wave rectification curve. However, it is well known that this curve contains only the even harmonics. To obtain the odd harmonics as well, a forward or reverse bias voltage must be applied. The amplitude of any harmonic, n, is then given by Eq. (1), where the generator voltage $V = V_0 \cos \omega t$, and I_0 is the peak current which would be obtained if the diode were absent.

$$A_n = \frac{I_0}{\pi} \frac{2}{n^2 - 1} \left[\frac{\sin n\theta \cos \theta}{n} - \cos n\theta \sin \theta \right] \quad (1)$$

where $$\cos \theta = -\frac{V_b}{V_0}$$

and V_b is the bias voltage.

We note that the terms in the bracket in Eq. (1) can have a maximum absolute value of about 1. Thus we can say approximately that A_n is proportional to $n^{1/2}$, and that the output power in the n-th harmonic P^n, is proportional to $n^{1/4}$.

Harmonic Generation with an Ideal Nonlinear Capacitance

We now consider the nonlinear capacitance. Let us first assume it to be ideal, with the following properties:

1. It has infinite capacitance when the applied voltage is in the forward direction.
2. All the stored charge is recovered when the voltage is reduced to zero.

Using these assumptions, we may predict the behavior of a harmonic generator using such a nonlinear device, with resistive terminations. From assumption (1) above, the nonlinear capacitance will have negligible reactance; hence the phase shift between voltage and current will be negligible also. Let the variation of current with time be represented by the dotted curve (*a*) in *Fig 1*. In accordance with assumption (2) the curve of charge *vs.* time will be represented by curve (*b*) for an ideal nonlinear capacitor.

In an actual diode, not all of the stored charge is recovered; some is lost through recombination. The charge-time relation will then be represented by a curve such as (*c*) in *Fig. 1*. A similar curve would result when using an ideal nonlinear capacitance with reverse bias. The built-in bias (turn-on voltage) of a real diode also accomplishes the same effect.

To analyze the harmonic output of the nonlinear capacitance diode, we note that curve (*c*) has a break similar to those found in the current *vs.* time curve of a rectifier. Thus in the Fourier expansion of this curve, the constant coefficient of the n-th harmonic term, B_n, will be approximately proportional to $1/n^2$. The n-th term in the expansion will be given by Eq. (2).

$$q_n = B_n \cos n\omega t \cong B \frac{1}{n^2} \cos n\omega t \quad (2)$$

where B is a quantity that does not vary much from term to term. The current i_n can be found by differentiation.

$$i_n = -(B\omega/n) \sin n\omega t$$

The harmonic current is approximately proportional to $1/n$, and the power to $1/n^2$. Thus the harmonic output power of the nonlinear capacitor should be approximately n^2 times as great as that of the nonlinear resistor.

As indicated above, working harmonic generators employing diodes should have provision for applying varying *d-c* bias in order to maximize harmonic output. However, a more detailed analysis shows that the output of the nonlinear capacitance is much less sensitive to bias changes than that of the nonlinear resistance.

The foregoing analysis of broadband operation makes no attempt at rigor, but it does illustrate the superiority of the nonlinear capacitor over the nonlinear resistor. Practical harmonic generators are not operated broadband, usually, but employ tuning to maximize the output of the desired harmonic. The performance of tuned harmonic generator circuits has been analyzed by other authors. C. H. Page[2] has shown that with a lossless nonlinear resistor, the maximum fraction of generator power that can be converted to the n-th harmonic is $1/n^2$. Manley and Rowe[3] have shown that for a lossless nonlinear reactance the maximum output at a single harmonic can approach one hundred per cent of the generator power.

The Actual Nonlinear Capacitance

The above results apply only to nonlinear elements without parasitics. An actual nonlinear capacitance diode has nonzero series resistance, which we represent by R_S. The quality factor for the device is then

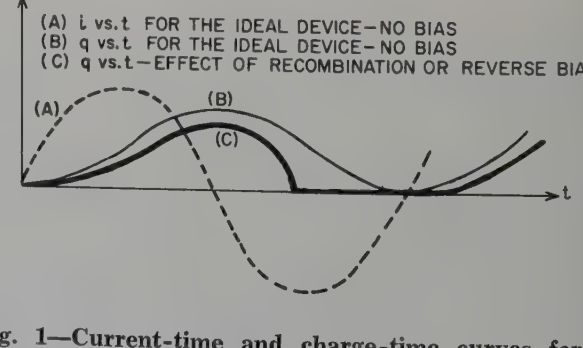

Fig. 1—Current-time and charge-time curves for the nonlinear capacitance.

given by $Q = 1/2\pi fCR_S$, where C is an average capacitance. At relatively low frequencies Q can be made sufficiently large by reverse-biasing the diode, thereby decreasing C. But as the frequency f increases, C cannot be reduced below a minimum value C_{min}, which is obtained when the bias voltage approaches the breakdown voltage. Thus the diode has a cut-off frequency f_c, for which $Q = 1$, defined by $f_c \cong 1/2\pi C_{min}R_S$. As the frequency of a harmonic approaches f_c, the output is greatly reduced below the value predicted for the ideal device. When operated at higher frequencies, the diffused junction diode will not have greater efficiency than the rectifier, but will nevertheless retain advantages of greater power handling capability and ruggedness.

The point-contact rectifier will not behave like the ideal device either. Power will be dissipated in the diode itself. On the other hand, harmonic generation at high frequencies may be enhanced by the variable capacitance of the depletion layer.

Subharmonic Generation

Another useful form of conversion of a single frequency is subharmonic generation. By the process of frequency subdivision, a standard frequency obtained from an atomic or molecular line spectrum may be converted to a low frequency standard.

It has been shown theoretically that a pure nonlinear resistance cannot generate subharmonics[2] but that a nonliner capacitance can.[3] The latter result follows from the Manley-Rowe theory of frequency conversion. These authors give generalized power relations for nonlinear reactances acting as frequency converters when driven by not more than two generators at different frequencies. For example, if the device is driven by a pump at frequency p and a signal at frequency s, stable gain will be obtained if power is taken out only at the sum frequency $p + s$; the gain is then equal to the ratio of the frequencies, $(p + s)/s$. On the other hand, if the circuit is tuned to permit power transfer at the signal frequency s and the difference frequency $p - s$, negative resistances appear at these two frequencies, and a large amount of amplification can be obtained without a change in frequency. Further, under proper tuning the device may go into oscillation, without application of a signal. In this way subfrequencies can be generated.

We can see that locking-in may be expected when $s = p/n$, where n is an integer. If $n = 2$, for example, the circuit will have a tank or cavity resonating at the one-half harmonic, $p/2$. The signal resulting from this oscillation will beat with the pump frequency to obtain a difference frequency which is again $p/2$. (The circuit, of course, has a negative resistance at this frequency.) The signal at $p/2$ may also be doubled by the nonlinear capacitance, producing power at the fundamental frequency, which will resonate in the input circuit. This resonance at $p/2$ is not infinitely sharp, of course. Oscillations will occur in a narrow band surrounding the one-half frequency. When the resonant circuit is slightly detuned, oscillations are obtained with reduced amplitude.

It is easy to see that locking-in will occur if the circuit be tuned to the frequencies $1/3\ p$ and $2/3\ p$. Resonances will occur with the sum and difference frequencies, as well as with multiples of these frequencies. Further we may expect locking-in to occur for higher values of n, but to a smaller extent.

From the above theoretical discussion it is seen that a considerable improvement can be expected in harmonic generators employing devices closely approximating an ideal nonlinear capacitor. The observed superiority of welded-contact over point-contact diodes was presumably due to the charge storage action of the former.

Graded Junction Silicon Diode as a Nonlinear Capacitance

A p-n junction diode has recently been developed which is an effective nonlinear capacitor.[4] It is made by diffusing a high concentration of impurities into single crystal silicon. The diffusion process results in a graded distribution of impurities extending to considerable distances on both sides of the junction. Associated with the gradient of impurities is an electric field whose direction is such as to retard carriers crossing the junction under a forward bias. The retarding field also speeds the return of these carriers when the forward bias is removed. The loss of these charges through recombination is thereby reduced, minimizing d-c conduction.

Another advantage is gained through the presence of a graded junction. The impurity concentration increases strongly with increasing distance from the junction; this produces a very small resistance in series with the junction. Thus the device has a high Q at microwave frequencies.

The nonlinear capacitor diode has been used with success as a low noise amplifier at microwave frequencies.[4] As may be expected, it is also an effective generator of harmonics and subharmonics. In Table I below are presented some experimental results obtained with the device. In both harmonic and subharmonic generation, filters were used to prevent power dissipation at unwanted frequencies, and tuning elements were employed to maximize output. A

TABLE 1
TUNED HARMONIC AND SUBHARMONIC GENERATION WITH A NONLINEAR CAPACITANCE DIODE

	FUNDAMENTAL (mc/sec)	HARMONIC (mc/sec)	CONVERSION LOSS (db)
HARMONIC GENERATION	330	990	7.8[4]
	430	860	5.3[4]
	1200	8,400	28.7[4]
	8910	44,500	45.7
SUBHARMONIC GENERATION	800	400	8

diagram of the circuit for harmonic generation is shown in *Fig. 2.*

The efficiencies listed for the second and third harmonics are considerably higher than those obtained with harmonic generators previously available and higher than predicted for broadband operation. We note, on the other hand, that the efficiency for generating a fifth harmonic at 44 kilomegacycles per second is much less than that for generating a seventh harmonic at 8 *kmc/sec.* Thus we may suspect that at 44 *kmc/sec* the diode has already exceeded the cutoff frequency discussed above, unless other aspects of the circuitry caused this low yield.

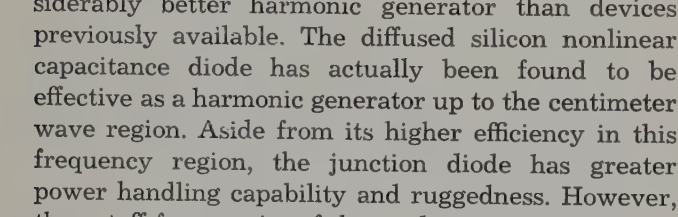

Fig. 2—Tuned harmonic generator.

Summary

We have seen that from theoretical considerations a nonlinear capacitance device ought to be a considerably better harmonic generator than devices previously available. The diffused silicon nonlinear capacitance diode has actually been found to be effective as a harmonic generator up to the centimeter wave region. Aside from its higher efficiency in this frequency region, the junction diode has greater power handling capability and ruggedness. However, the cutoff frequencies of the nonlinear capacitors now available are well below the millimeter wave region. To obtain the full advantage of nonlinear reactance action at these extremely high frequencies will require a new advance in semiconductor art.

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- Radiation Effects on Semiconductors
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Large Signal Characteristics Of The Silicon Unijunction Transistor

T. P. SYLVAN*

The silicon unijunction transistor is a unique device which features a stable negative resistance characteristic, a stable firing voltage and a very low firing current. A simple equivalent circuit for the unijunction transistor is derived from the construction of the device and its theory of operation. This equivalent circuit is then used to describe the important electrical characteristics and to predict their variation with bias point and temperature.

[Tear sheets of this article are available on written request]

WITH AN INCREASING NUMBER of semiconductor devices becoming available, it is important for the circuit designer to understand the unique features of each device and to know the general type of circuit application for which each device is particularly suited. Many semiconductor devices have analogs in vacuum tube devices which aid in the understanding of their electrical characteristics and their circuit applications. However, aside from the superficial similarity to the gas thyratron the unijunction transistor has no such vacuum tube analog and for this reason requires a more comprehensive study for full appreciation of its possible applications. Most of the more important applications of the unijunction transistor make use of one or more of its four unique characteristics: (1) a stable firing voltage (V_P) which is a fixed fraction of the supply voltage, (2) a very low firing current (I_P), (3) a stable negative resistance characteristic, and (4) a high pulse current capability.

Construction and Theory of Operation

A cross-sectional diagram of the unijunction transistor is shown to scale in *Fig. 1a*. A ceramic disk having the same expansion coefficient as silicon is used as the mounting platform. A gold film is deposited on both sides of a 10 mil slit in the center of the disk. A single crystal *n*-type silicon bar having a resistivity of about 120 ohm-cm and dimensions of about 8 x 10 x 35 mils is laid across the slit and two ohmic base contacts are formed between the silicon and the gold. The two base contacts are called base-one (B1) and base-two (B2). A single *p*-type emitter (E) junction is formed by a 3 mil diameter aluminum wire on the side of the silicon bar opposite from the base contacts. The emitter junction is usually located closer to base-two than base-one so the device is not symmetrical. Symmetrical units are obtained if the emitter junction is an equal distance from the two base contacts, but such units do not have optimum electrical characteristics for most applications.

The resistance measured between base-one and base-two with the emitter open circuited is called the *interbase resistance* (R_{BB}). In the equivalent circuit of *Fig. 1c*, the interbase resistance is represented by the series resistors R_{B1} and R_{B2}. The interbase resistance is generally specified at 25°C and a low interbase voltage and lies within the range between 4.7K and 9.1K.[1] The interbase resistance increases linearly with temperature up to about 140°C with a temperature coefficient of about 0.8%/°C at 25°C. Below 140°C, the temperature coefficient is determined by the temperature coefficient of the carrier mobility; above 140°C the temperature coefficient becomes negative because of the increase of thermally generated carriers in the silicon. The interbase resistance increases slightly with interbase voltage, an increase of 5% at 40 volts being typical. For most practical purposes, however, the interbase resistance may be considered as being ohmic.

To understand the operation of the unijunction transistor consider base-one as grounded and a constant voltage, V_{BB}, applied at base-two in *Fig. 1*. The voltage V_{BB} causes a potential gradient within the silicon bar and produces a voltage at the emitter junction which is a fraction, η, of the interbase voltage. This fraction η is called the *intrinsic standoff ratio* and in the equivalent

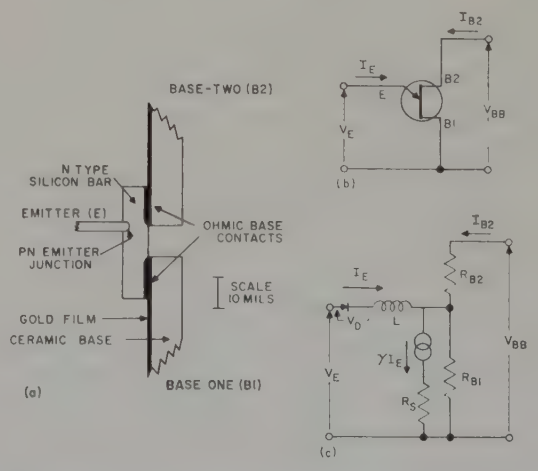

Fig. 1—Cross-sectional diagram and equivalent circuit of the unijunction transistor.

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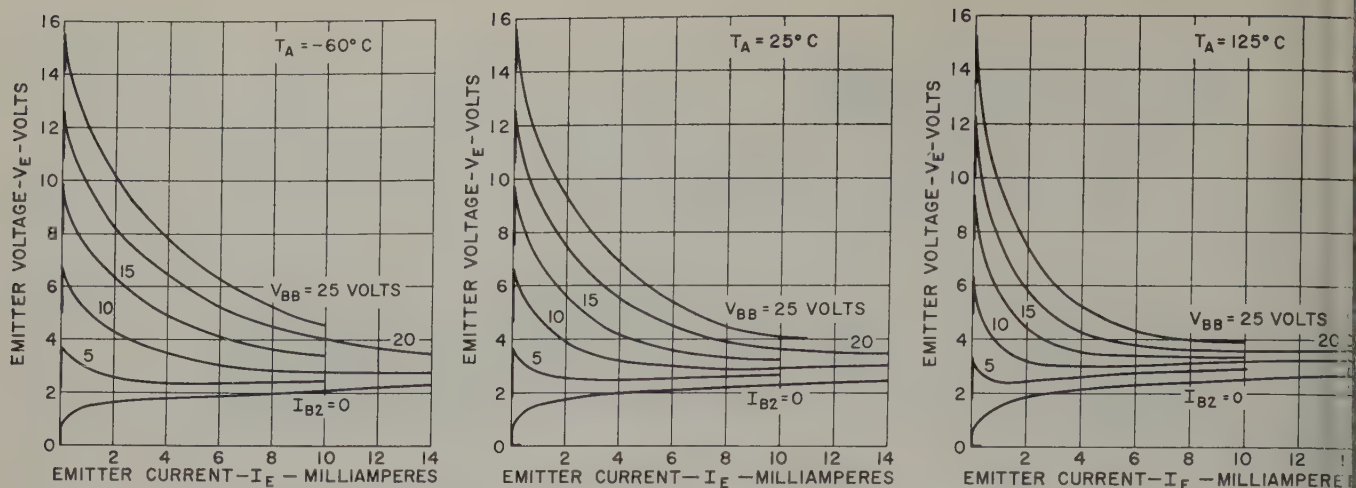

Fig. 2—Static emitter characteristics of the unijunction transistor. (Type 2N492)

circuit is determined by the relative values of R_{B1} and R_{B2}.

$$\eta = \frac{R_{B1}}{R_{B1} + R_{B2}} = \frac{R_{B1}}{R_{BB}} \qquad (1)$$

If the applied emitter voltage, V_E, is less than $\eta\ V_{BB}$ the emitter junction will be reverse biased and only a small leakage current, I_{E0}, will flow. If the emitter voltage is slightly greater than $\eta\ V_{BB}$, the emitter junction will be forward biased and will inject holes into the silicon bar. These holes will move down the bar towards base-one under the influence of the potential gradient and will result in an equal increase in the electron concentration. The increase in carrier concentration between emitter and base-one will cause the resistance of the region to decrease by conductivity modulation. Thus the emitter voltage will decrease as the emitter current increases producing a negative resistance characteristic as shown in *Fig. 2*.

The emitter characteristic curves such as those shown in *Fig. 2* are the most important design curves of the unijunction transistor. It is found that these characteristic curves are quite uniform from one unit to another and as indicated in *Fig. 2* are relatively independent of temperature. Two important points exist for each interbase characteristic curve, the *peak point* and the *valley point*. The *peak point* is defined as the point at which the emitter voltage has its maximum value. The values of the emitter voltage and current at the peak point are called the *peak point voltage* (V_P) and *peak point current* (I_P). The *valley point* is defined as the point at which the emitter voltage has its minimum value for a positive emitter current. The values of emitter voltage and current at the valley point are called the *valley point voltage* (V_V) and *valley point current* (I_V). The region to the left of the peak point where the emitter diode is reverse biased is called the *cutoff region*. The region between the peak point and the valley point is called the *negative resistance region* and the region to the right of the valley point is called the *saturation region*.

The current generator γI_E in *Fig. 1c* represents the effective current gain between emitter and base-one which results from the conductivity modulation previously described. If the emitter diode is assumed to have an ideal injection coefficient and the carrier lifetime is much greater than the transit time from emitter to base-one, it can be shown [2] that,

$$\gamma = \frac{\mu_N}{\mu_P} - 1 \cong 4 \qquad (2)$$

Where μ_N is the electron mobility and μ_P is the hole mobility in silicon. If γ is assumed to be constant the equation of the emitter characteristic in the negative resistance region is

$$V_E = V_D + \eta\ V_{BB} - (\gamma - 1)\ \eta\ (1-\eta)\ R_{BB} I_E \qquad (3)$$

where V_D is the voltage drop across the emitter diode. Actually γ will not be constant but will vary according to the transit time and effective lifetime of carriers in the emitter to base-one region. If the lifetime is assumed to be independent of the current level, the transit time will be determined by the voltage between emitter and base-one so that

$$\gamma = (V_E - V_D)\ \gamma_0 \leq \frac{\mu_N}{\mu_P} - 1 \qquad (4)$$

where γ_0 is a constant. Using this expression, the equation for the emitter characteristic becomes,

$$V_E = V_D + \frac{I_E R_T + \eta\ V_{BB}}{1 + \gamma_0\ R_T\ I_E} + I_E\ R_s \qquad (5)$$

where

$$R_T = \frac{R_{B1}\ R_{B2}}{R_{B1} + R_{B2}} = \eta\ (1-\eta)\ R_{BB}$$

The resistance R_s is the ohmic resistance between emitter and base-one and is generally in the range of 5 to 10 ohms. It is found experimentally that Equation 5 describes the emitter characteristic curves over the full range of emitter current with a high degree of accuracy.

The interbase characteristic curves shown in *Fig. 3* are used in conjunction with the emitter characteristic curves for the complete description of the static characteristics of the unijunction transistor. The curve for $I_E = 0$ corre-

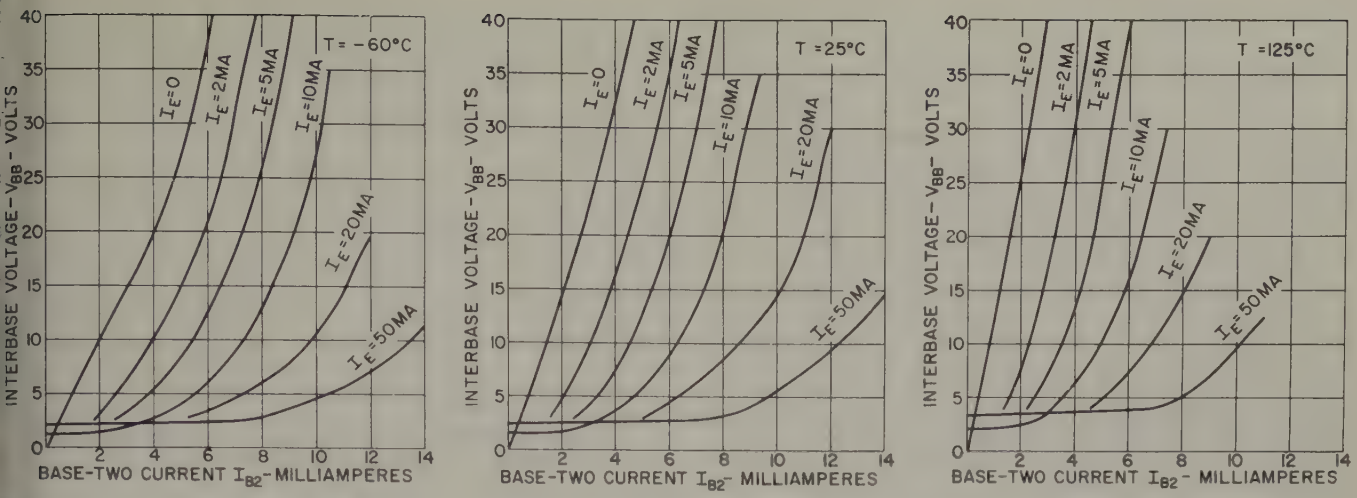

Fig. 3—Static interbase characteristics of the unijunction transistor. (Type 2N492)

ponds to the interbase resistance. The nonlinearity of his curve is caused by the heating effect of the interbase current and the consequent increase of R_{BB} with temperature. Note that there is a small effective current gain between emitter and base-two which results from a slight conductivity modulation of the region between emitter and base-two. The equivalent circuit of *Fig. 1c* can be used to describe the interbase characteristics if a second current generator is added between base-one and base-two.

In the emitter characteristic curves of *Fig. 2*, the lower curve is measured with base-two open circuited and thus may be considered as the emitter to base-one diode curve. The emitter to base-one diode voltage can be measured in terms of two components, the emitter to base-two voltage V_{EB2} shown in *Fig. 4*, and the base-two to base-one voltage V_{B2B1} shown in *Fig. 5*.

$$V_{EB1\ (diode)} = V_{EB2} + V_{B2B1}$$

It is seen in *Fig. 4* that the emitter to base-two diode characteristic is similar to the characteristic of a conventional silicon diode. The base-two to base-one characteristic of *Fig. 5* is seen to approximate a resistance in parallel with a logarithmic element. It is found that Equation 5 describes this characteristic if V_{BB} is set equal to zero. Note that V_{EB2} has a negative temperature coefficient and V_{B2B1} has a positive temperature coefficient so that the emitter to base-one voltage can have a zero temperature coefficient for a certain value of emitter current. For the unit having the characteristics shown in *Figs. 4* and *5* this condition occurs at an emitter current of about 0.3 milliamperes.

The peak point voltage is given in terms of η and V_{BB} by the equation;

$$V_P = V_D + \eta V_{BB} \qquad (6)$$

In the equivalent circuit of *Fig. 1c*, the intrinsic standoff ratio is determined by the values of R_{B1} and R_{B2} according to Equation 1. Both R_{B1} and R_{B2} are temperature dependent but can be expected to have the same temperature coefficient so that η is independent of temperature. A circuit for the precise measurement of η and V_D is shown in *Fig. 6*. In this circuit the interbase voltage is

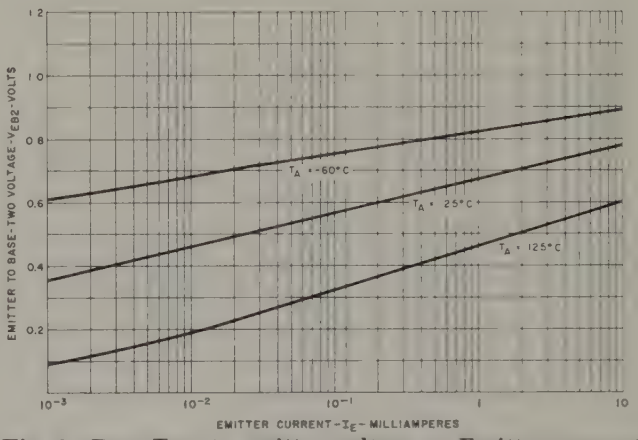

Fig. 4—Base-Two to emitter voltage *vs* Emitter current with Base-Two open circuited. (Type 2N492)

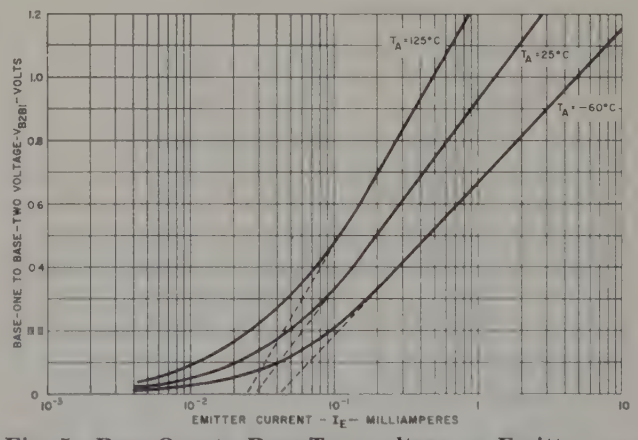

Fig. 5—Base-One to Base-Two voltage *vs* Emitter current with Base-Two open circuited. (Type 2N492)

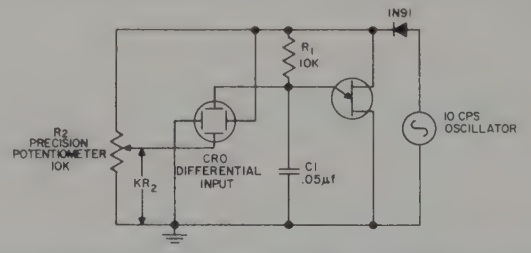

Fig. 6—Circuit for measurement of intrinsic standoff ratio η and equivalent emitter diode voltage V_D

swept by the 10 *cps* oscillator while the unijunction transistor oscillates at a frequency of about 2 *kc* determined by R_1 and C_1. The interbase voltage is applied to the horizontal axis of the oscilloscope. The emitter voltage is applied to one input of the vertical differential amplifier and the potentiometer voltage is applied to the other input. The oscilloscope pattern then consists of a plot of V_{BB} on the horizontal axis against

$$V_P - KV_{BB} = V_D + (\eta - K)\ V_{BB}$$

where K is the fractional setting of the potentiometer. Note that V_P is the upper envelope of the emitter voltage. If K is set equal to η the upper envelope will be horizontal and the displacement from the zero axis will be equal to V_D. If a precision potentiometer is used for R_2, η can be measured with an accuracy of better than 0.05% and V_D can be measured to within 20 millivolts. Using this method of measurement, it is found for most unijunction transistors that η varies less than $\pm 0.01\%/°C$ and V_D varies about -3 *mv*/°C. Thus it is seen that the variation in V_P with temperature is primarily caused by the change in V_D. It is possible to compensate for the variation of V_P with temperature by making use of the temperature variation of the interbase resistance R_{BB}. If a resistor R_2 is used in series with base-two the interbase voltage will increase with temperature because of the temperature variation of R_{BB}. If the proper value of R_2 is used for given values of η, R_{BB} and supply voltage V_1, the temperature coefficient of V_P may be reduced to zero. The approximate value of R_2 for this condition is;

$$R_2 \cong \frac{0.65\ R_{BB}}{\eta\ V_1} \qquad (7)$$

It is interesting to note that with a resistor of this value in series with base-two the peak point voltage is equal to $\eta\ V_1$. This method of temperature compensation is ideal in that the temperature compensating element (R_{BB}) is in intimate physical contact with the element which requires compensation (the emitter diode). For this reason errors in compensation due to changes in power dissipation or sudden changes in ambient temperature are avoided.

If the equivalent circuit of *Fig. 1c* is accurate, the emitter characteristic in the neighborhood of the peak point could be represented by an ideal diode in series with a fixed negative resistance. The theoretical characteristic is shown in *Fig. 7* and is seen to give an accurate representation of the actual measured characteristics. From this, it may be deduced that the peak point current will vary inversely with the magnitude of the negative resistance at the peak point. According to Equation 5, the magnitude of the negative resistance at the peak point is proportional to the interbase voltage so it is to be expected that the peak point current will be inversely proportional to the peak point voltage or the interbase voltage. The variation of I_P with V_{BB} is shown in *Fig. 8* for several values of temperature. It is seen that the peak point current decreases with increasing temperature as would be expected from the variation of the emitter characteristic curves with temperature (*Fig. 2*).

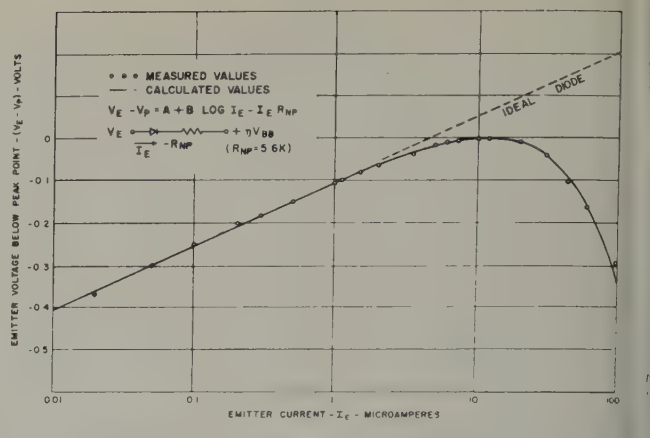
• • • MEASURED VALUES
— · CALCULATED VALUES
$V_E - V_P = A + B \log I_E - I_E R_{NP}$
V_E
$+\eta V_{BB}$
I_E
$-R_{NP}$
(R_{NP}=5.6K)
IDEAL DIODE
EMITTER VOLTAGE BELOW PEAK POINT - ($V_E - V_P$) - VOLTS
EMITTER CURRENT - I_E - MICROAMPERES

Fig. 7—Unijunction transistor static emitter characteristics at peak point. (V_{BB} = 15v; T_A = 25°C)

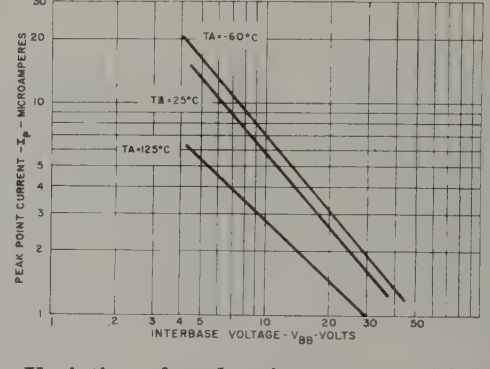

Fig. 8—Variation of peak point current with interbase voltage and ambient temperature.

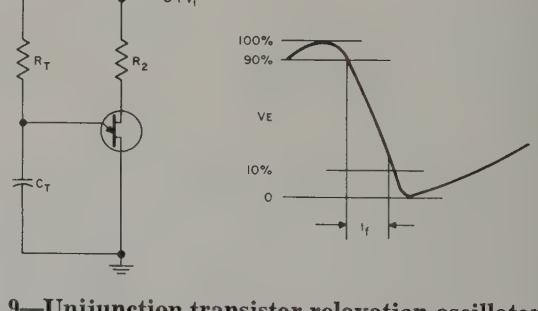

Fig. 9—Unijunction transistor relaxation oscillator with emitter voltage waveform.

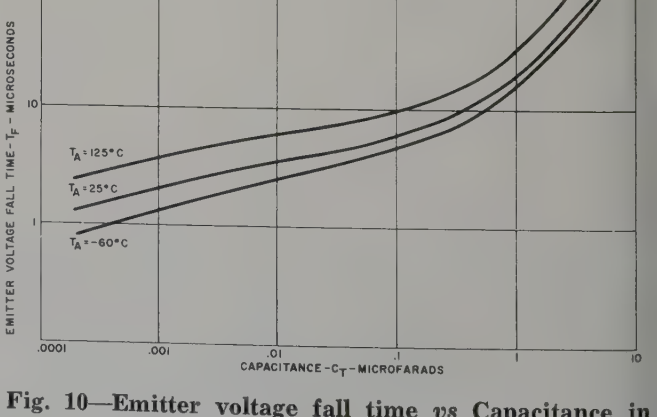

Fig. 10—Emitter voltage fall time *vs* Capacitance in relaxation oscillator.

Switching Characteristics

The inherent limitation in the switching speed of the unijunction transistor can be understood by a consideration of *Fig. 1*. The holes and electrons within the silicon bar move in a strong electric field so that the transit time of an individual carrier can be very short, in some cases less than .01 microsecond. However, in switching between the cutoff and conducting state, holes are injected at the emitter and the electrons originate at base-one. The charge concentration must build up slowly since space charge neutrality must be maintained and thus a large number of transit times are required in switching to the conducting state. The inductance in the equivalent circuit represents this frequency limitation and lies in the range from 1 to 10 millihenries. The inductive effect is apparent even when the unijunction transistor is used as a diode with base-two open circuited. A sudden increase in forward current will result in a voltage spike across the diode.

The switching speed or frequency response of the unijunction transistor can be specified in a variety of ways.[3] [4] A practical approach is to specify the fall time of the emitter voltage waveform in the relaxation oscillator circuit of *Fig. 9*. The fall time (t_f) is defined as the time between the 90% and 10% voltage points of the emitter voltage. The fall time is shown in *Fig. 10* as a function of the capacitance C_T. For the higher values of C_T, the ohmic resistance R_s is the principal factor determining the fall time.

The triggering requirements of the unijunction transistor are best specified in terms of the minimum trigger amplitude required with a specified trigger pulse width. This characteristic is shown in *Fig. 11* for a positive trigger at the emitter or a negative trigger at base-two. As the trigger width increases, the required trigger amplitude approaches the *d-c* values. Note that the required amplitude at base-two is $1/\eta$ times as large as the required amplitude at the emitter. The effective charge which is required for triggering is about one millimicrocoulomb.

If the unijunction transistor is conducting between emitter and base-one, it may be turned off by reverse biasing the emitter with respect to base-one. The recovery time, t_r, is defined as the length of time the emitter must be reverse biased before a positive emitter bias less than V_P may be applied without re-establishing the conducting state. The measurement of this recovery time is much different than the measurement of the recovery time for a conventional transistor. A basic measurement circuit is shown in *Fig. 12*. The output voltage of generator "A" is set greater than the static value of peak point voltage V_{P0}. The unijunction transistor then turns on for the duration of pulse A. A pulse from generator "B" occurs at a time τ after the end of the first pulse. This pulse has an amplitude V_B which is less than V_{P0}. By decreasing the time interval τ until the unijunction transistor just fires at the second pulse it is possible to measure the instantaneous value of V_P as a function of time. Measured values of V_P as a function of time are shown in *Fig. 13*.

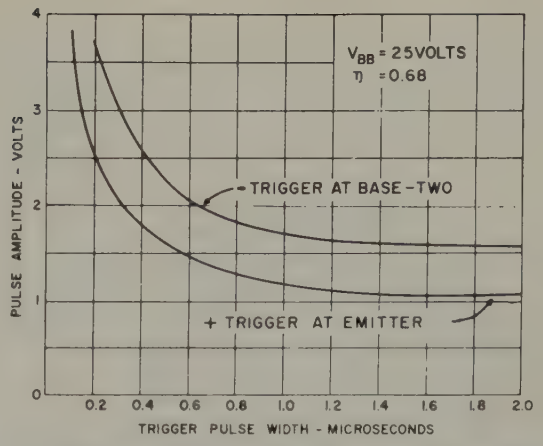

Fig. 11—Minimum trigger amplitude as a function of trigger pulse width for "turn on" of unijunction transistor.

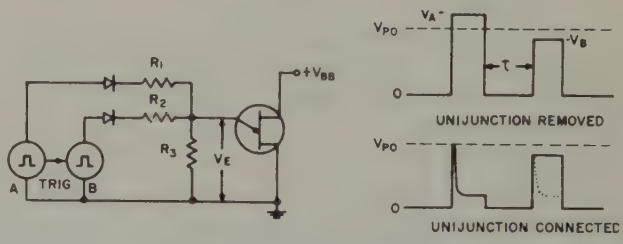

Fig. 12—Test circuit for measurement of peak point voltage recovery time with typical emitter voltage waveform.

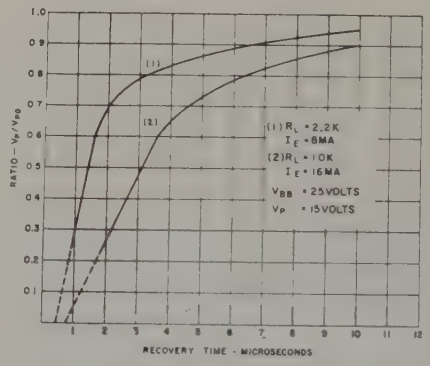

Fig. 13—Recovery characteristic of peak point emitter characteristics for two values of emitter current.

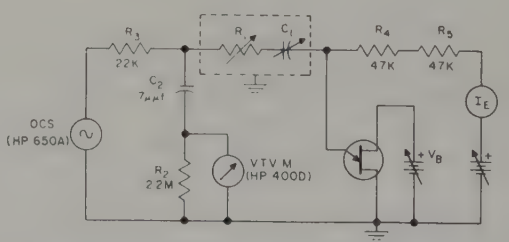

Fig. 14—Circuit for measurement of emitter input impedance of unijunction transistor.

As is to be expected, the recovery time increases as the initial emitter current increases or as the effective carrier lifetime in the silicon bar increases.

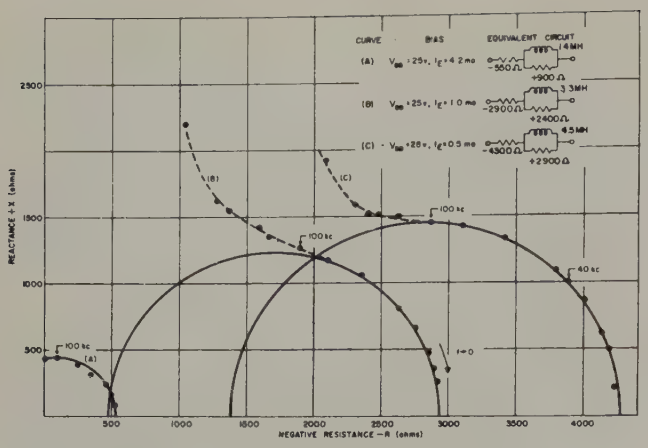

Fig. 15—Emitter impedance diagram of unijunction transistor at several bias points.

The small signal frequency response of the unijunction transistor in the negative resistance region can be measured with the circuit shown in *Fig. 14*. The emitter bias current is supplied through resistors R_4 and R_5. The oscillator and resistor R_3 serve as an *a-c* current generator. Resistor R_1 and capacitor C_1 are adjusted to obtain a null on the *vtvm*. When a null is obtained, it is known that the input impedance of the unijunction transistor is equal to $-R_1 + j/\omega C_1$. The capacitor C_2 reduces the possibility of oscillation of the circuit in a relaxation oscillator mode and also serves in conjunction with R_2 as a high pass filter to improve the null on the *vtvm*.

An impedance diagram for a unijunction transistor at several different bias points is shown in *Fig. 15*. It will be noted that in the low frequency range below about 100 *kc*, the input impedance is represented by a network composed of an inductance, one positive resistance and one negative resistance.

Corresponding to the alpha cutoff frequency of a conventional transistor a *"resistance cutoff frequency"* f_{R0} may be defined for the unijunction transistor. This is the frequency at which the resistance component of the input impedance becomes zero, and represents the maximum frequency at which the unijunction transistor can oscillate at a particular bias point. It is found that f_{R0} is a function of the bias point and can be best presented in the form of contours of constant f_{R0} superimposed on the emitter characteristic curves. A typical plot is shown in *Fig. 16*. It will be noted that f_{R0} increases as the peak point is approached and as a limit approaches f_{max}, the maximum frequency of oscillation in a relaxation oscillator circuit. It is also found that the value of f_{R0} at any bias point is proportional to the magnitude of the negative resistance at that point. This indicates that the carrier transit time is the important factor in determining both the negative resistance and the resistance cutoff frequency.

Circuit Requirements

Most applications of the unijunction transistor are based on the simple relaxation oscillator shown in *Fig. 9*. This is the basic circuit for sawtooth wave generators, pulse generators, time delay circuits, phase control circuits, multivibrators, triggering circuits, one-shot multivibrators etc. Any semiconductor device which is to give optimum performance in all of these circuits must satisfy several conditions;

(1) The peak point voltage or firing voltage must be stable with temperature since this determines the stability of the frequency or timing period. By the proper choice of the compensating resistor R_2 in the unijunction transistor circuit, it is possible to obtain a peak point stability approaching $\pm .001\%/°C$.

(2) The peak point current or firing current should be stable with temperature and have a low value. This permits a long time delay with a capacitor C_T of minimum size. For example, with a 30 volt supply and the unijunction transistor having the characteristics shown in *Fig. 8*, it is possible to obtain up to 6 seconds of period for each microfarad of capacity. With the unijunction transistor, it is possible to reduce the effective firing current by as much as 100 to 1 by means of a small amplitude *a-c* signal at base-two.

(3) The negative resistance characteristic should be uniform from unit to unit and stable with temperature and the valley current should be large. A large valley current permits oscillation with small values of R_T. The load line formed by R_T and V_1 must intersect the emitter characteristic curve to the left of the valley point otherwise oscillation will not be possible. For the unit having the characteristic shown in *Fig. 2*, oscillation would be

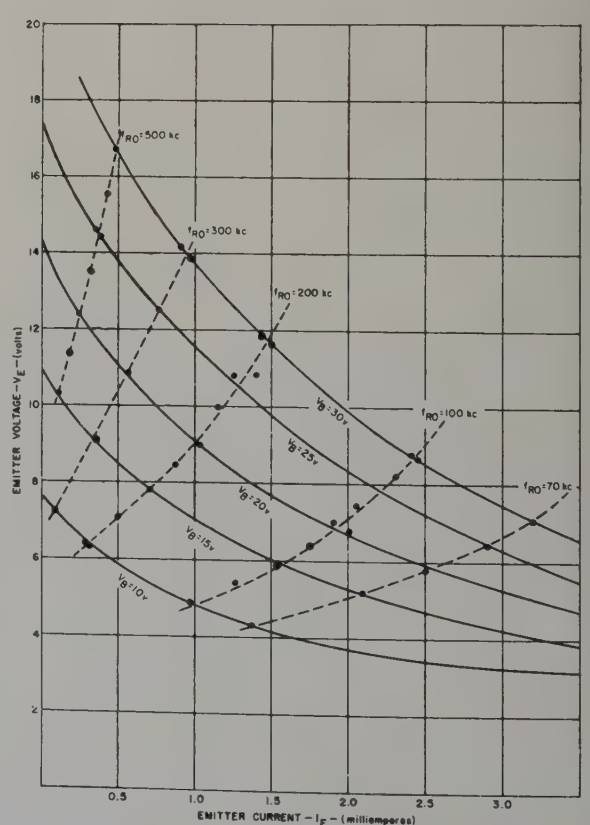

Fig. 16—Unijunction transistor emitter characteristic curves with contours of constant resistance cutoff frequency (f_{R0})

possible with values of R_T as low as 2.0K at a supply voltage of 20 volts and at an ambient temperature up to 125°C. A stable negative resistance characteristic as evidenced by *Fig. 2* permits the unijunction transistor to be used in applications such as Q multipliers.

(4) The emitter leakage current, I_{E0}, should be low at the highest temperature of operation. The emitter leakage current acts as a charging current for the capacitor C_T and hence can cause an appreciable error in the timing period. The typical values for the emitter leakage current at 10 volts are 3 millimicroamperes at 25°C and 2 microamperes at 150°C. The minimum breakdown voltage of the emitter diode is 60 volts.

(5) The peak current rating of the device should be rge si nce this permits rapid discharge of the timing capacitor C_T and the generation of large amplitude current pulses. The unijunction transistor is rated at two amperes peak current at a junction temperature of 150°C.

References

(1) T. P. Sylvan, "Unijunction Transistor Test Set," *Semiconductor Products,* September 1958, pp. 25-27.
(2) J. J. Suran, "Low Frequency Theory of the Double-Base Diode," *IRE Trans.—Electron Devices,* ED-2, April 1955, p. 40.
(3) J. J. Suran, "Small Signal Wave Effects in the Double-Base Diode," *IRE Trans.—Electron Devices,* ED-4, January 1957, pp. 34-43.
(4) B. K. Eriksen, J. J. Suran, "Transient Response Characteristics of Unijunction Transistors," *IRE Trans.—Circuit Theory,* CT-4, September 1957, pp. 267-275.

A Production Method For Measurement of Rise, Fall, and Storage Time

DONALD G. PATERSON, M.A.Sc.*

The most accurate measurement of switching transistor pulse response requires the use of a high speed oscilloscope and is time consuming for even a skilled operator. This article describes a method by which rise, fall, and storage time can be measured rapidly with relatively simple and inexpensive equipment. The accuracies obtained are within the limits of human error and the method is completely adaptable to production techniques.

[Tear sheets of this article are available on written request]

A METHOD SUITABLE FOR PRODUCTION measurement of collector rise, fall, and storage time without elaborate equipment and with adequate accuracy has been developed. The technique involves differentiation of the collector waveform slopes for rise and fall time measurement and averaging of a voltage pulse, whose length is proportional to storage time for storage time measurement.

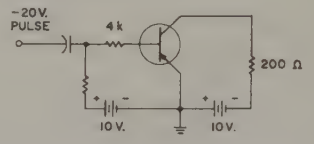

Fig. 1—Typical switching transistor test circuit.

Rise and Fall Time

A negative voltage pulse with very short rise and fall times and sufficient amplitude to produce saturation is applied from base to emitter of a normally off *p-n-p* transistor, *Fig. 1,* and the collector waveform in *Fig. 2* results. Section "A" shows the transistor's response to the leading edge of the pulse and defines rise time as the interval between the 10-90% of maximum amplitude points. During this interval, the waveform exhibits an essentially constant positive slope, and during section "C"—a constant negative slope, corresponding to fall time. A brief analysis shows that differentiation of these edges results in positive and negative spikes whose amplitudes are proportional to rate of rise and fall (and hence rise and fall time), respectively. By separating these spikes into their respective polarities with steering diodes and directing them through peak reading circuits, a connected meter may be calibrated in microseconds to read rise and fall time (See *Fig. 3*).

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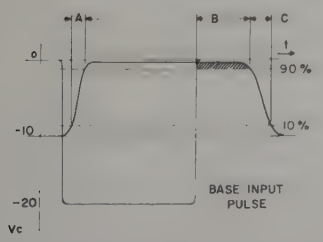

Fig. 2—Collector wave form resulting from pulse applied to input of circuit shown in Fig. 1.

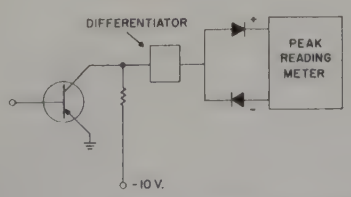

Fig. 3—Circuit for reading rise and fall times.

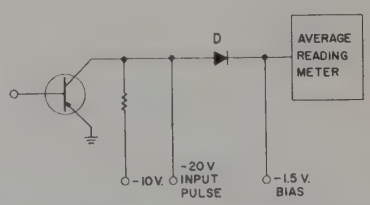

Fig. 4—Circuit for reading storage time.

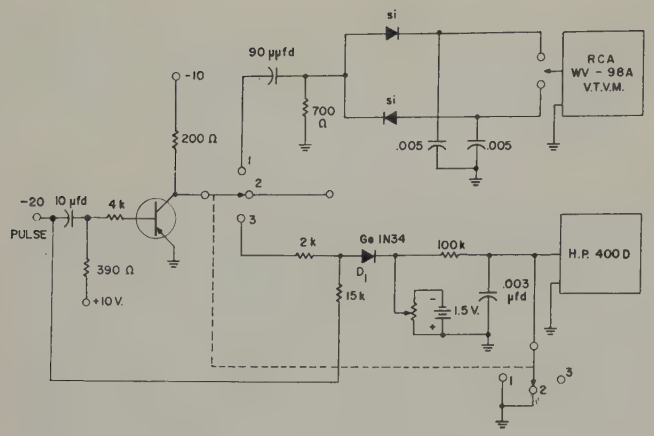

Fig. 5 — Complete circuit of the measurement unit.

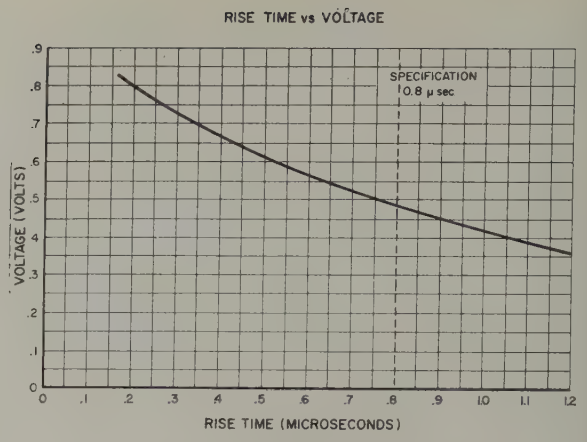

Fig. 6 — Rise Time *vs.* Voltage.

Storage Time

Since fall time is measured between the 10% and 90% values, storage time is considered to be the interval between the end of the input pulse and the 90% value (section "B" of *Fig. 2*). If the small hatched area of the collector waveform *(Fig. 2)* were available as a pulse, it could be directed through an integrating circuit, or into an average reading meter, to provide a reading approximately proportional to storage time. The approximation is poor for very small values of storage time or very long fall times, but neither limitation would affect its production use.

The circuit requirements in order to obtain this pulse are that no voltage or current be sampled during the time the input pulse is on and the instantaneous collector voltage is below 90% of its maximum value. A circuit capable of performing this operation is shown in *Fig. 4*. The semiconductor diode D_1 is biased in the reverse direction by the input pulse and, hence, allows no output during the time the input pulse is present. Owing to the negative 1.0 volt bias battery, the diode conducts during the interval when the instantaneous collector voltage is above –1 volt, or, as in the case of a 10 volt collector supply, above the 90% value. Isolation to prevent overloading the averaging meter is provided by the 100K–.003*mf* *RC* combination in the final circuit, *(Fig. 5)*, since readings are made on a very sensitive range. (Subsequently, an amplifier was added to the basic circuit to improve accuracy).

The semiconductor diode D_1 closes rapidly on removal of the input pulse, but opens more gradually due to the less abrupt change in collector voltage when the transistor turns off. This introduces some error if transistor fall time is long or storage time is short, and suggests rejection of slow units before storage is measured.

Rise and fall times are measured in position No. 1 of the selector switch, while storage time is measured in position No .3. Position No. 2 may be used for oscilloscope monitoring of the collector waveform.

Evaluation of Method

Curves have been obtained for rise, fall, and storage time *vs.* voltage from a number (50) of samples and are shown in *Figs. 6, 7* and *8*. The units used for storage time measurements all fell within specifications on rise and fall time. Accuracy of the method appears to be within ±.03μsec. for rise and fall time measurements and ±.025μsec. for storage time.

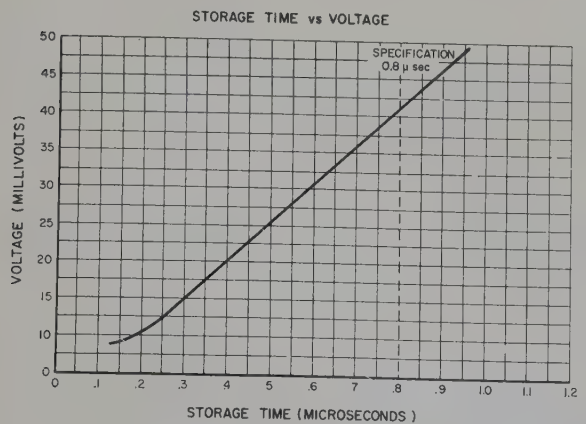

Fig. 7 — Fall Time *vs.* Voltage.

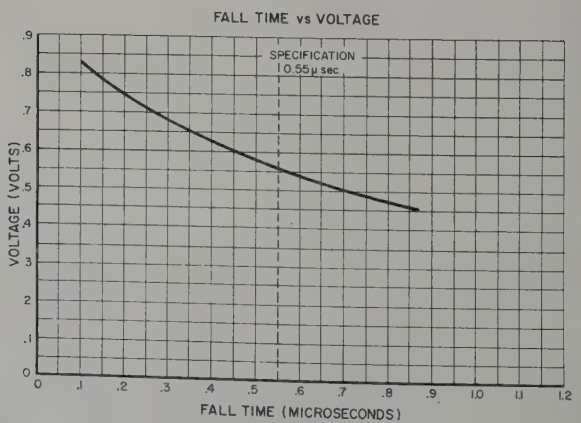

Fig. 8 — Storage Time *vs.* Voltage.

Flow Graph Analysis of Transistor Feedback Networks

DR. PETER KAUFMANN* and JOHN J. KLEIN**

The flow graph technique is used for analyzing the four basic transistor feedback circuits. The input and output resistances, and voltage and current gains are calculated for the common-emitter and the common-base configurations. The common-collector configuration is approximated with a series voltage feedback. Equivalent circuit examples are given for all four basic circuits and their properties are discussed. The final section demonstrates the analysis of an example of multistage feedback for a series voltage configuration.

[Tear sheets of this article are available on written request]

THE FLOW-GRAPH technique for solving linear systems problems has been the subject of some recent papers.† Unlike other methods for solving linear network problems, it has the advantage of showing visually the inter-relationships of the variables in the system. This visualization helps to give a better understanding of the effect of the circuit parameters on the system's performance. It has also been shown in reference 2 (Equation 12) that the relation between input and output of any flow graph configuration is extremely easy to analyze by Mason's method. The purpose of this paper is to illustrate how the signal flow graph may be used to analyze feedback in transistor circuits.

The transistor is often referred to as an active, linear, four-terminal network. Two linear equations interrelating the terminal voltages and currents (i.e. v_1, v_2, i_1, and i_2) are all that are needed to describe completely the properties of any four-terminal network. The form of these equations depends on the choice of the dependent and the independent variables. The choice of variables leads to the various systems of parameters such as hybrid, impedance, admittance, etc.

Flow-Graph Representation of the Four-Pole Network

The well-known h-parameter equivalent circuit for an active linear four-pole network is shown in *Fig. 1a* where i_1 and v_2 are the independent parameters and v_1 and i_2 are the dependent parameters. The circuit equations are:

$$v_1 = i_1 h_{11} + v_2 h_{12} \quad (1)$$

$$i_2 = i_1 h_{21} + v_2 h_{22} \quad (2)$$

These equations yield the four-terminal flow-graph shown in *Fig. 1b*. This graph displays pictorially the dependencies implied in Eq. (1) and (2). The terminal characteristics of the circuit in *Fig. 1a* may be written directly from the *Fig. 1b* flow graph.

For example, in calculating the input resistance, the total flow from the independent variable concerned (i_i) to the dependent variable (v_i) is noted. A version of the flow graph of *Fig. 1b*, modified to include the output termination, is useful for determining the input impedance. (See *Fig. 2.*)[1]

The graph of *Fig. 2* leads to the following equation for input impedance if the basic rules of flow graph

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†See "References" at conclusion of article.

[1]The negative sign of the load resistance (and in later figures of the generator resistor) is a result of the definitions of the current and voltage directions.

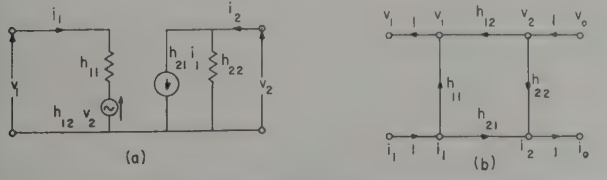


Fig. 1. Equivalent circuit and flow-graph of a linear four-pole network.

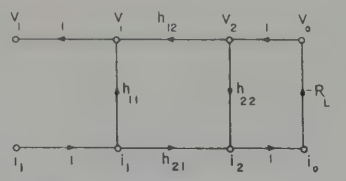


Fig. 2. Flow-graph for determining input resistance.

calculation (Ref. 1 and 2) are properly applied.

$$r_i = \frac{v_i}{i_i} = h_{11} + \frac{h_{21}\, h_{12}\, (-R_L)}{1 + h_{22}\, R_L}. \qquad (3)$$

Using the same graph, the equation for current gain may also be obtained. That is:

$$A_i = \frac{i_o}{i_i} = \frac{h_{21}}{1 + h_{22}\, R_L}. \qquad (4)$$

The output conductance follows from *Fig. 3.*

$$g_o = \frac{i_o}{v_o} = h_{22} + \frac{h_{12}\, h_{21}\left(-\frac{1}{R_g}\right)}{1 + \frac{h_{11}}{R_g}}. \qquad (5)$$

$$g_o = h_{22} - \frac{h_{12}\, h_{21}}{R_g + h_{11}}. \qquad (6)$$

The voltage gain of the circuit of *Fig. 1a* is easily derived by multiplying the current gain by the ratio of the load resistance to the input resistance. That is:

$$A_v = \frac{v_o}{v_i} = \frac{i_o\, R_L}{i_i\, r_i} = -A_i\, \frac{R_L}{r_i}. \qquad (7)$$

$$A_v = -\frac{h_{21}\, R_L}{h_{11} + R_L\, |h|}. \qquad (8)$$

where

$$|h| = h_{11}\, h_{22} - h_{12}\, h_{21}.$$

Analysis of the Four Basic Feedback Circuits by Flow-Graph

The four basic feedback circuits of an active, linear, four-pole network are shown in *Fig. 4.* The terminology in the figure mentioned is such that the first word characterizes the feedback in the input circuit and the second word applies to the output configuration. The expression "series current feedback," for example, tells that the feedback power is in series with the input configuration and the power originates from an output current source.[2] The gain and the effective impedance expressions of these circuits are derived in the next few paragraphs with the aid of the signal flow-graph.

In the following analysis, the effect of h_{12} on the terminal characteristics is considered negligible. This assumption is justified for both the common-emitter and common-base configurations, provided that the *a-c* load impedance is much less than the open-circuit output impedance, and that the *a-c* generator resistance is much greater than the short-circuit input impedance. For most low-frequency applications, the above assumption is valid. A circuit in which the effect of h_{12} cannot be neglected will be discussed later.

[2]Note that in *Fig. 4b* and *4d*, the feedback voltage appears as a negative quantity; this is because of the directions assumed for voltage and current in the four-pole network. Also note that the distinction between voltage and current feedback disappear when the load Z_L is a resistance.

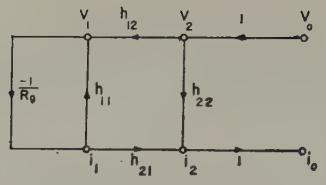


Fig. 3. Flow-graph for determining output conductance.

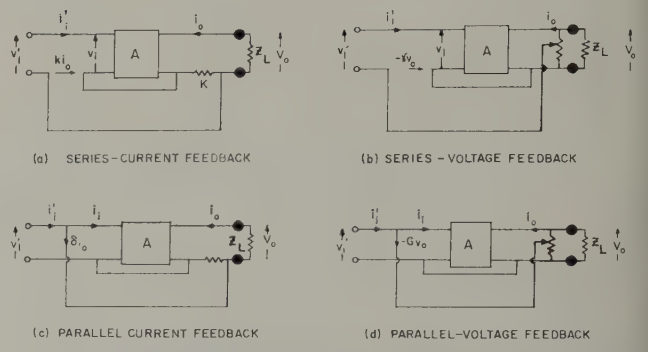


Fig. 4. Basic types of feedback.

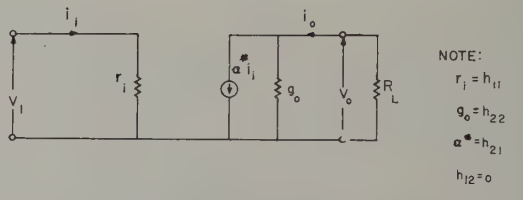


Fig. 5. Simplified equivalent circuit.

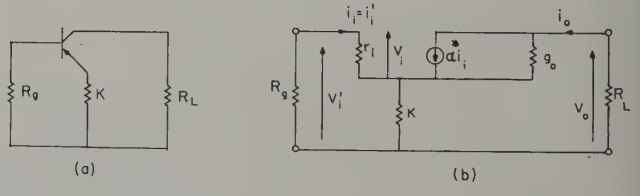
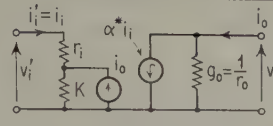
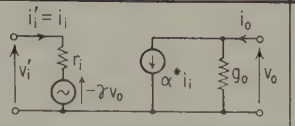
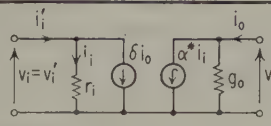
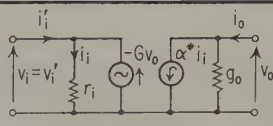
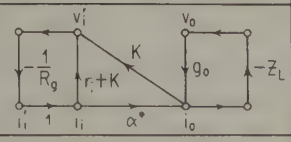
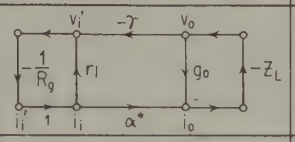
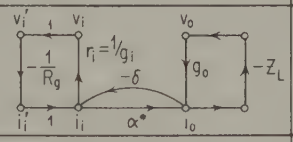
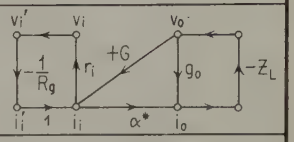
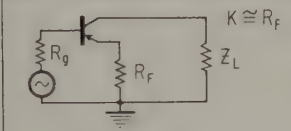
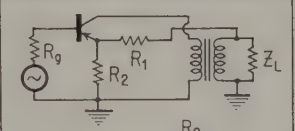
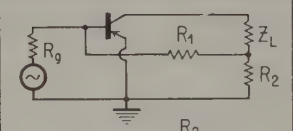
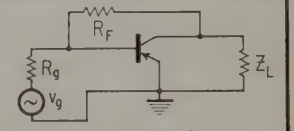


Fig. 6. Grounded-emitter amplifier and equivalent circuit.

Figure 5 shows a simplified equivalent transistor circuit without feedback for either the common-base or the common-emitter configurations. Using the simplified equivalent circuit of *Fig. 5* and applying the circuitry interpretation to the four feedback types, the equivalent feedback configurations can be seen. The equivalent circuits for the four basic feedback connections, along with their corresponding flow-graphs, are shown in Table I. The equations for current gain, input resistance, and output conductance, which may be derived directly from the flow-graphs, are also stated in Table I. A circuit analysis is required to explain the flow-graph configurations belonging to the equivalent circuits. The following example calculation is intended to clarify Table I.

TABLE I

NOTE: $a_1 = \frac{1}{1+g_0 Z_L}$

	SERIES CURRENT FEEDBACK	SERIES VOLTAGE FEEDBACK	PARALLEL CURRENT FEEDBACK	PARALLEL VOLTAGE FEEDBACK
EQUIVALENT CIRCUIT				
EQUATIONS	$v_i' = i_i(r_i + K) + i_o K$ $v_o = 1/g_o (i_o - \alpha^* i_i)$	$v_i' = i_i r_i - \gamma v_o$ $v_o = 1/g_o (i_o - \alpha^* i_i)$	$i_i = i_i' - \delta i_o$ $v_o = 1/g_o (i_o - \alpha^* i_i)$	$i_i = i_i' + G v_o$ $v_o = 1/g_o (i_o - \alpha^* i_i)$
FLOW GRAPH				
OUTPUT RESISTANCE (Conductance)	$r_o' = r_o \left[1 + \frac{\alpha^* K}{r_i + K + R_g}\right]$	$g_o' = g_o \frac{\gamma \alpha^*}{R_g + r_i}$	$r_o' = r_o \left[1 + \frac{\alpha^* \delta R_g}{R_g + r_i}\right]$	$g_o' = g_o \frac{G \alpha^* R_g}{R_g + r_i}$ If $R_g \gg r_i$ and $g_o \ll G\alpha^*$ then $g_o' = G\alpha^*$
INPUT RESISTANCE (Conductance)	$r_i' = r_i + K\left[1 + \alpha^* a_1\right]$	$r_i' = r_i + \alpha^* \gamma Z_L a_1$	$g_i' = g_i (1 + \alpha^* \delta a_1)$	$g_i' = g_i (1 + G \alpha^* Z_L a_1)$
CURRENT GAIN	$A_i = \alpha^* a_1$	$A_i = \alpha^* a_1$	$A_i = \frac{\alpha^* a_1}{1 + \alpha^* a_1 \delta}$ If $\alpha^* a_1 \delta \gg 1$ then $A_i = 1/\delta$	$A_i = \frac{\alpha^* a_1}{1 + a_1 \alpha^* G Z_L}$ If $a_1 \alpha^* G Z_L \gg 1$ then $A_i = 1/GZ_L$
VOLTAGE GAIN	$A_v = \frac{-\alpha^* a_1 Z_L}{r_i + K[1 + \alpha^* a_1]}$ If $r_i \ll K[1 + \alpha^* a_1]$ and $\alpha^* a_1 \gg 1$, $A_v = -Z_L/K$	$A_v = \frac{-\alpha^* a_1 Z_L}{r_i + \alpha^* a_1 \gamma Z_L}$ If $r_i \ll \alpha^* \gamma Z_L a_1$ then $A_v = -1/\gamma$	$A_v = -\alpha^* a_1 Z_L g_i$	$A_v = -\alpha^* a_1 Z_L g_i$
EXAMPLES	 $K \cong R_F$ $R_F < Z_L \ll r_o$	 $\gamma \cong \frac{R_2}{R_1 + R_2}$	 $\delta \cong \frac{R_2}{R_1 + R_2}$	 $G \cong 1/R_F$

Consider the common-emitter amplifier with the unbypassed emitter resistor K shown in *Fig. 6a*. This resistor is useful in stabilizing the voltage gain of the amplifier. The *a-c* equivalent circuit is illustrated in *Fig. 6b*. Normally resistor K is less than R_L which is much less than the open circuit output impedance r_o, hence its effect may be neglected in a consideration of the output circuit, and the approximate *a-c* equivalent in *Fig. 7* will result. The flow of the current i_o through K cannot be neglected in the input circuit and is represented in *Fig. 7* as the current source i_o. This equivalent circuit of *Fig. 7* is the same circuit pictured in the first column of Table I under the heading of series-current feedback.

The other equivalent circuits shown in Table I can be explained in a similar manner. Note that the four basic types of feedback are neatly defined by the feedback paths on the various flow-graphs. For example, the feedback path on the flow-graph shown in column 1 demonstrates visually the dependence of the input voltage on the output current.

Discussion of Feedback Configurations

A comparison of the terminal parameters of the four basic feedback circuits with those of the non-feedback circuit is presented in Table II. This table is valid, subject to the assumptions previously made, provided that the feedback shown in the circuits of Table I is inverse. Observe that series feedback tends to increase input resistance, while parallel feedback decreases it. On the other hand, the output resistance will either increase or decrease for either current or voltage feedback, respectively. Note also that series and parallel feedback stabilize either voltage or current gain respectively.

Table II should help the transistor circuit designer in choosing the proper type of feedback to satisfy given circuit requirements such as stabilization of voltage gain, etc.

Common Collector Circuit

The common collector configuration has to be con-

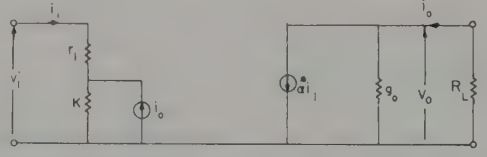


Fig. 7. Approximate equivalent circuit illustrating series-current feedback.

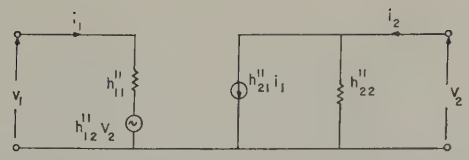


Fig. 8. Equivalent circuit for common-collector amplifier.

sidered separately from the other transistor circuits, because $h''_{12} = 1$ and cannot be neglected as in common-emitter and common-base circuits. The common collector configuration is shown in *Fig. 8*. It is obvious that this equivalent circuit corresponds to the series-voltage feedback configuration shown in Table I. Therefore, the grounded collector circuit has the same properties as the series-voltage feedback circuit with $\gamma = h_{12} = 1$.

Flow-Graph Analysis of Multistage Feedback

The use of the flow-graph technique in evaluating the results of feedback in a multistage amplifier is especially desirable. For example, a two-stage amplifier has to be designed with an extremely stable voltage gain. As shown in Table II, series current and series voltage feedback provide this quality. In the circuit drawn in *Fig. 9a*, the desired stable voltage gain is obtained by means of a series voltage feedback loop over both stages, and a series current feedback in the first stage.

TABLE II. Properties of the Four Basic Feedback Configurations

(Common Emitter and Common Base)

Circuit	r_i	r_o	A_i	A_v
Series Current Feedback	increased	increased	no influence	stabilized
Series Voltage Feedback	increased	decreased	no influence	stabilized
Parallel Current Feedback	decreased	increased	stabilized	no influence
Parallel Voltage Feedback	decreased	decreased	stabilized	no influence

Note: This table is generally also valid for $h_{12} \neq 0$

The *a-c* equivalent circuit for *Fig. 9a* is easily drawn, (*Fig. 9b*), assuming that $r_o \ll R_1$ and the load resistance is included in r_o.

$$r_o = \frac{Z_L}{Z_L\, g_{d2} + 1} \tag{9}$$

The *a-c* equivalent circuit for *Fig. 9b* can be simplified to that shown in *Fig. 10*.

If an assumption is now made for the first transistor similar to that which was made in the calculation of series current feedback (*Fig. 6* and *7*), a further simplified equivalent circuit can be obtained. *Fig. 11* pictures this final circuit, which requires that

$$(R_p + r_{i2}) \ll \frac{1}{g_{d1}} \tag{10}$$

The flow graph (*Fig. 12*) for the final circuit of *Fig. 11* can be drawn. Note that both the equivalent circuit and the flow-graph show series current feedback in the first stage in addition to an overall series voltage feedback. The assumptions made for this

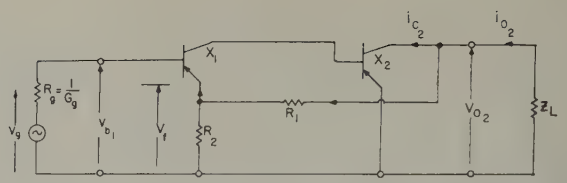


Fig. 9a. Multistage series voltage feedback circuit.

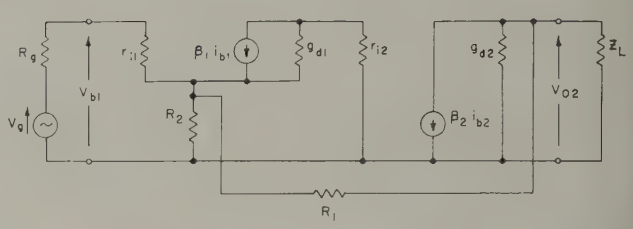
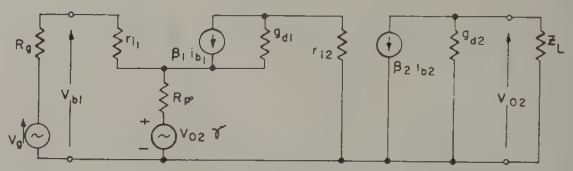


FIGURE 9b A-C EQUIVALENT CIRCUIT OF FIGURE 9a

Fig. 9b. A-C equivalent circuit of Fig. 9a.



$$R_p = \frac{R_1 \cdot R_2}{R_1 + R_2} \text{ and } \gamma = \frac{R_2}{R_1 + R_2}$$

Fig. 10. Simplified equivalent circuit of Fig. 9b.

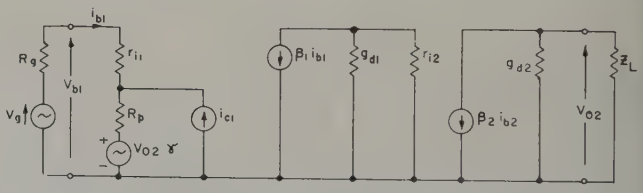


Fig. 11. Further simplified equivalent circuit.

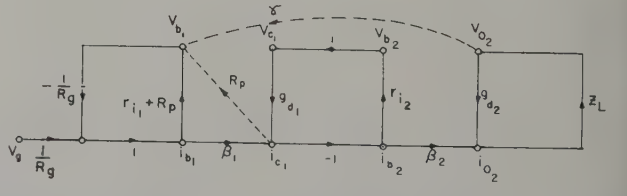


Fig. 12. Flow-graph of series voltage feedback over two stages. The solid lines show the basic flowgraph of the two-stage amplifier without feedback. The addition of feedback is indicated by the dotted lines.

xample are, of course, not necessary for drawing the low-graph. Also, the gain and impedance formulas which are here derived for the simplified case, can asily be obtained for the general circuit using Mason's rules. The formulas become so complex, however, that it is impossible to distinguish what is important from what is unimportant.

The equation for the input impedance,

$$i = r_{i1} + R_p + \frac{\beta_1 R_p}{1+g_{d1} r_{i2}} + \frac{\beta_1 \beta_2 Z_L \gamma}{(1+g_{d1} r_{i2})(1+g_{d2} Z_L)} \quad (11)$$

nd also the following ones can again be obtained with Mason's rule, or the consequent simplification of he flow-graph.

Output conductance:

$$o = g_{d2} + \frac{\gamma \beta_1 \beta_2 R_g}{(R_g+r_{i1}+R_p)(R_g+\beta_1 R_p)(1+g_{d1} r_{i2})} \quad (12)$$

Current gain:

$$A_i = \frac{-\beta_1 \cdot \beta_2}{(1+g_{d1} r_{i2})(1+g_{d2} Z_L)} \quad (13)$$

Voltage gain: $A_v = -A_i \frac{Z_L}{r_i}$

or

$$A_v = -\frac{\beta_1 \beta_2 Z_L}{\beta_1 \beta_2 Z_L \gamma + (1+g_{d2} Z_L)[(1+g_{d1} r_{i2})(r_{i1}+R_p)+\beta_1 R_p]} \quad (14)$$

The terminal equations show that the input resistance is increased while the output resistance is reduced. The current gain is not affected by the series voltage feedback .

If $\beta_1 \beta_2 Z_L \gamma \gg (1+g_{d2} Z_L)[(1+g_{d1} r_{i2})(r_{i1}+R_p)+\beta_1 R_p]$

which is quite often the case, since g_{d1} and g_{d2} are small numbers, the voltage gain is:

$$A_v = \frac{-1}{\gamma} \quad (15)$$

It is obvious from Eq. (15) that this type of feedback tends to stabilize the voltage gain.

Acknowledgment

This subject matter was developed during the preparation of lecture notes for a transistor circuitry course at Northeastern University given jointly by the two authors. The authors wish to thank Dr. W. W. Happ for demonstrating the usefulness of flow-graphs in transistor circuits and encouraging their use in this application.

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Radio Noise In Semiconductor Devices

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When used to rectify a-c circuits, semiconductor devices generate radio noise in excess of airborne electronic specification limitations. The same characteristic noise has been found in germanium, selenium, and silicon and in various brands and types of semiconductor devices. It does not result from defects or from exceeding performance capabilities of the devices. Silicon devices exhibit higher noise levels. Radio interference suppression by restriction of operational ratings does not appear to be a promising technique but conventional filter techniques are adequately effective.

[Tear sheets of this article are available on written request]

THE RAPID GROWTH in number and complexity of electronic systems required for military aircraft and missiles has made miniaturization of electronic packages a matter of critical importance. The reduction in volume offered by substitution of compact semiconductor devices in lieu of more bulky vacuum tubes has provided the circuit designer with a promising solution to many of his ever-mounting space reduction problems.

In addition, semiconductor devices in airborne equipment are often significantly superior to vacuum

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tubes and other rectifiers with respect to reliability, efficiency, resistance to shock and vibration, and anticipated useful life. Consequently, the use of semiconductors in airborne military electronic systems has grown astronomically in the past few years.

As might be anticipated, while airborne electronic systems have been mushrooming in quantity and becoming many times as complicated, the problems of interaction between systems have also multiplied. Newer, more sensitive systems are increasingly susceptible to radio noise interference; furthermore, they are located in closer conjunction to more numerous and more powerful electronic systems. For this reason, radio noise limitation requirements imposed by military specifications upon the design of individual systems have been found to be inadequate to protect such systems from interaction. More stringent limitations have therefore been found necessary, requiring the application of a broader range of test frequencies and more refined measurement techniques.

Recent observations of radio interference interactions between a group of airborne electronic systems indicated the desirability of conducting a series of laboratory tests to determine the degree to which such interference might be originated by semiconductors. It was suspected that these components were producers of noise, in certain applications, of such levels as to either preclude their use or to require special filtering techniques or circuit redesign before the semiconductor devices could be used in aircraft having numerous separate complex electronic systems.

Tests were therefore designed to investigate the radio-noise behavior of different types of such devices, provided by different manufacturers. Measurements were taken to provide information as to the general characteristics, magnitude, and source of radio noise.

Test Conditions

The test circuit shown in *Fig. 1* permitted independent variation of frequency, voltage, and current, and was used to test rectifiers and diodes under several combinations of conditions. A majority of the test effort was directed towards obtaining information on silicon diodes since it had been determined from previous tests that this type of semiconductor device had generated the greatest amount of radio noise interference.

An inquiry directed to the manufacturers of the particular semiconductor devices which were being evaluated, established that all had obtained hyperpure silicon from the same source. Consequently, for the purpose of obtaining preliminary approximate information, it was not considered desirable to make exhaustive comparative tests of devices from all manufacturers.

The test results indicated that the semiconductor devices generated radio noise which fluctuated in response to variations in voltage, frequency, and current. No significant variation was detected as a result of change in temperature or of manufacturer. However, the test results clearly indicated that under many conditions of operation, the radio noise generated in semiconductor devices is in excess of the limits permitted by Specification Mil-I-6181C for frequencies up to 5 megacycles.

At their lower ratings, selenium and germanium devices exhibited nearly the same noise level as correspondingly rated silicon devices.

Effects of Frequency, Current, and Voltage Variations

Figure 2 illustrates a typical increase of radio noise in a silicon rectifier as a function of frequency and current. It will be noted that the radio noise levels at corresponding currents average about 20 decibels higher at 400 cycles per second than at 60 cycles per second. This characteristic was demonstrated in all other tests conducted; that is, higher frequency produced increased radio interference.

Figure 3 demonstrates a typical increase of radio interference in a silicon diode as a result of increased

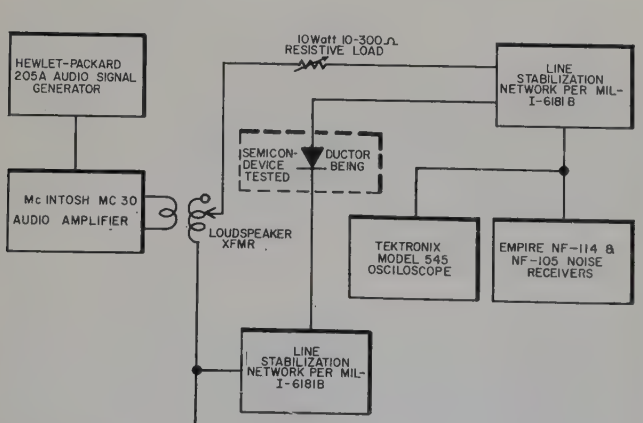
HEWLET-PACKARD 205A AUDIO SIGNAL GENERATOR
10 Watt 10-300Ω RESISTIVE LOAD
LINE STABILIZATION NETWORK PER MIL-I-6181B
SEMICONDUCTOR DEVICE TESTED
Mc INTOSH MC 30 AUDIO AMPLIFIER
LOUDSPEAKER XFMR
TEKTRONIX MODEL 545 OSCILLOSCOPE
EMPIRE NF-114 & NF-105 NOISE RECEIVERS
LINE STABILIZATION NETWORK PER MIL-I-6181B

Fig. 1 — Test circuit for measurement of radio noise in semiconductor devices.

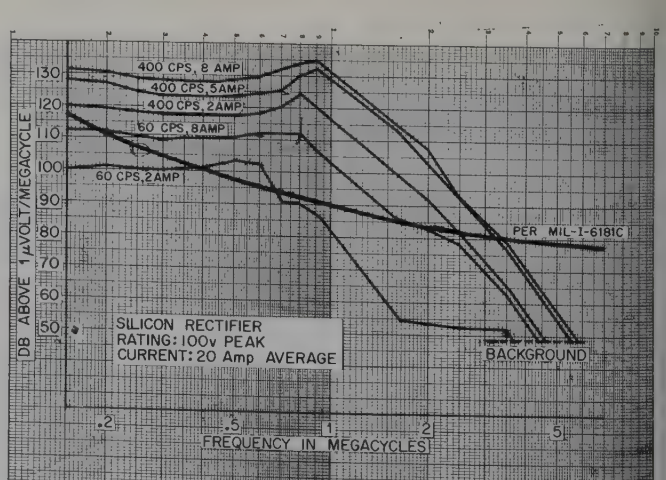

Fig. 2 — Variations of radio noise with respect to frequency and current in a silicon rectifier.

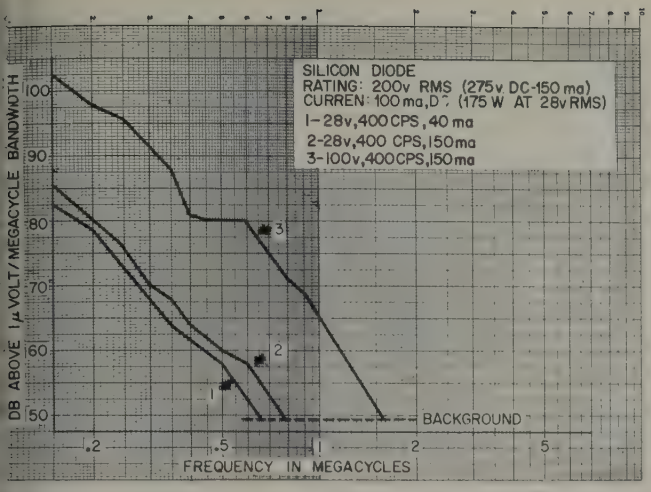
SILICON DIODE
RATING: 200v RMS (275v DC-150 ma)
CURRENT: 100 ma, DC (175 W AT 28v RMS)
1-28v,400 CPS, 40 ma
2-28v,400 CPS, 150ma
3-100v,400 CPS, 150ma
DB ABOVE 1μ VOLT/MEGACYCLE BANDWIDTH
BACKGROUND
FREQUENCY IN MEGACYCLES

Fig. 3 — Variations of radio noise with voltage in a silicon diode.

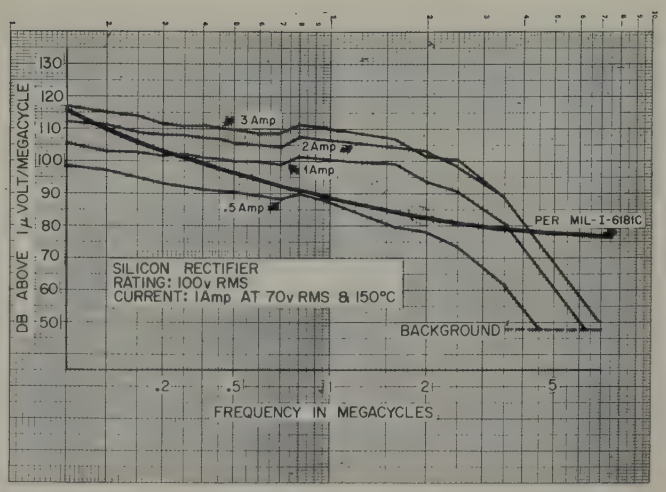

Fig. 4 — Variations of radio noise with current in a silicon rectifier.

voltage in which substitution of a 100 volt power supply in lieu of a 28 volt power supply produced an increase in noise level of about 20 decibels. The relatively small magnitude of this increase conversely demonstrates how little can be achieved in reducing radio interference by lowering voltages.

Figures 2, 3, and *4* all illustrate that higher noise levels result when current is increased. In the silicon rectifier test illustrated by *Fig. 2*, a 6 ampere increase in current produced an average of about 10 decibels increase in radio noise. In the silicon diode test illustrated by *Fig. 3*, an increase of current from 40 milliamperes to 150 milliamperes resulted in an average increase of about 5 decibels in noise level. In the silicon rectifier test illustrated by *Fig. 4*, an increase in current of 1 ampere caused an average increase of about 5 decibels in noise level.

Variations in operating temperature produced no significant variations in noise level.

Filtering Techniques

Several simple filters were investigated. Techniques employed included the placement of ferrite beads on the leads of the semiconductor devices, the insertion of capacitors across the test units, and the placement of ferrite beads on the leads of the capacitors inserted across the test units. In the latter application, changing the number of beads on the capacitor leads provided a method for adjustment of the series resonant frequency of the capacitor so that the filter could be tuned to the most critical noise frequency in order to minimize the noise level. As illustrated in *Figs. 6, 7,* and *8*, maximum filtration was accomplished using ferrite beads on the leads of capacitors across the semiconductor devices.

The oscilloscope photographs, *Fig. 5*, apparently demonstrate that radio noise in a semiconductor device is generated by a sharp pulse of small relative magnitude which occurs at the beginning of each conducting half cycle. This pulse is characterized by a very sharp leading edge followed by a gradual trailing edge which resembles in its configuration an exponentially damped sine wave. Since there is a delay between the application of an electrical potential and the injection of sufficient carriers to conduct the applied current, the voltage increases abruptly at the beginning of the conduction cycle and decays as more carriers are injected and conduction is initiated. Similarly, at the end of the cycle, the carriers remaining in the semiconductor will transmit energy in the

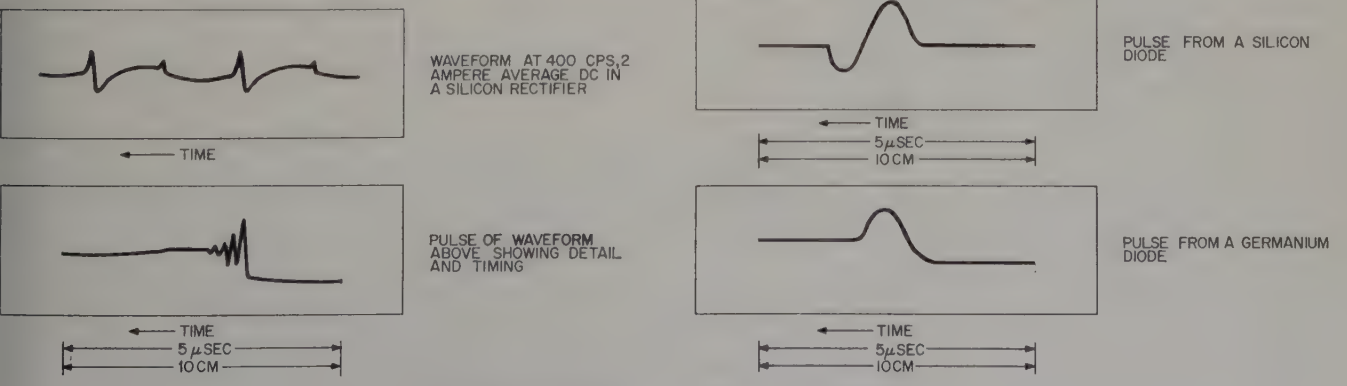

Fig. 5 — Wave form studies of rectifiers.

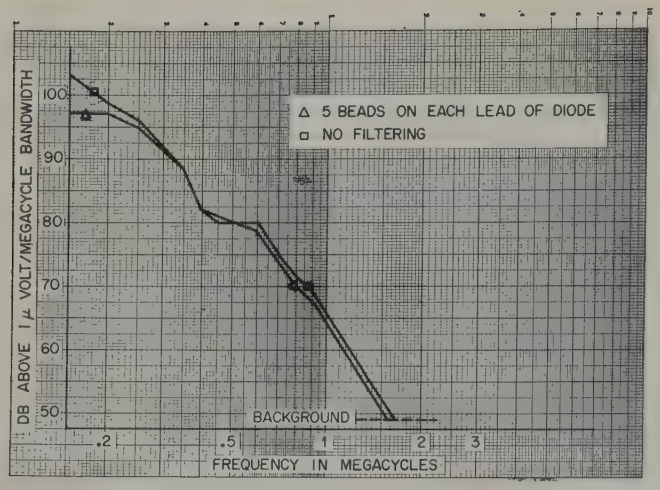

Fig. 6 — Filtering of radio noise produced by placement of ferrite beads on leads of a silicon diode.

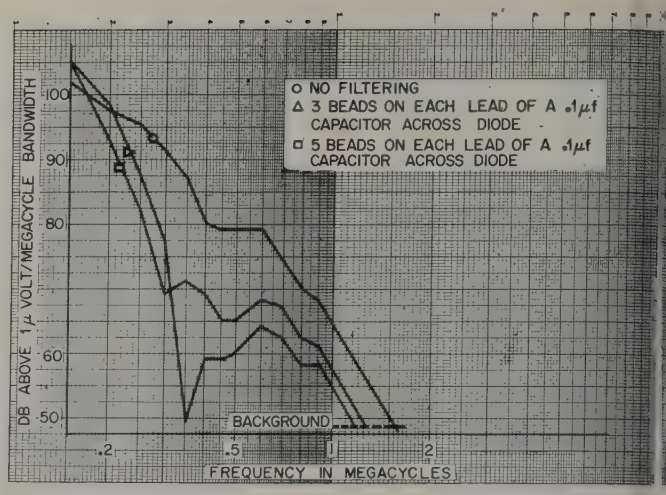

Fig. 7 — Filtering of radio noise and variation in absorption frequency produced by varying the number of ferrite beads on leads of a capacitor placed across a silicon diode.

reverse direction until all of them are exhausted, causing a reverse current pulse. The noise problem in silicon is of greater magnitude since its higher energy gap allows higher voltage ratings.

The cyclic noise effects demonstrated in *Fig. 5* have not previously been presented in semiconductor literature. Noise theory discussions are generally limited to "shot noise" or "Zener effect."

Summary

In summary, this laboratory experiment provided the following conclusions:

(1) Semiconductor diodes and rectifiers when used to rectify *a-c* current generate radio noise which is generally greatly in excess of specification requirements for airborne electronic equipment. This noise is inherent in the material and does not result from any flaws or manufacturing defects, or from exceeding rated performance capabilities.

(2) The same characteristic noise exists in both germanium and selenium and in all brands and types of diodes and rectifiers used in these tests. The noise level in silicon devices exhibits a tendency to be greater, possibly due to the fact that silicon has a higher energy gap.

(3) Suppression of radio interference noise by restriction of operational ratings does not appear to be a promising technique within the limits of the series of experiments performed since indications obtained are that the performance penalties would be unduly severe.

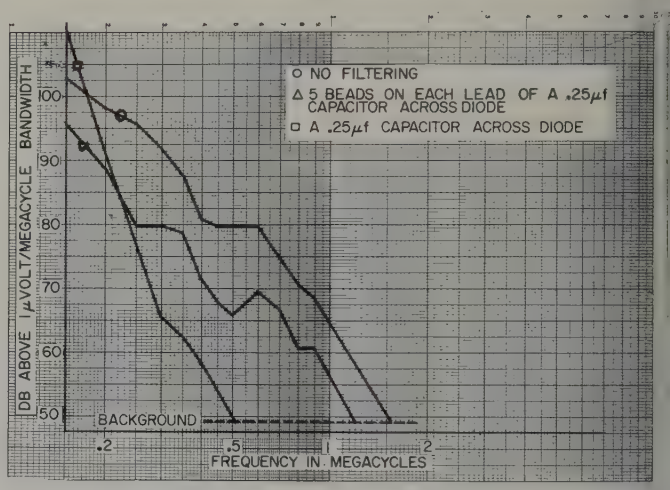

Fig. 8 — Filtering of radio noise produced by a capacitor across a silicon diode and by placement of ferrite beads on capacitor leads.

(4) Suppression of radio noise in semiconductor devices yields readily to conventional filter techniques and presents no unusual problems.

Power Dissipation In Diode Clippers

WALTER B. MITCHELL*

The computation of the power dissipated in a semiconductor regulator diode can be quite difficult to calculate. In this article, equations are derived for the power dissipated for two cases: a very small duty cycle, and also a half sine wave. Nomographs are given to facilitate solution of these problems. These nomographs may also be used in calculating the power dissipated in rectifiers during forward conduction as well as in regulator, or Zener diodes.

Tear sheets of this article are available on written request

AN EVER INCREASING USE of semiconductor diodes is as clippers. The general case of the power dissipated is rather difficult to calculate, but there re special cases which are fairly easy to solve. A ypical diode clipper is shown in *Fig. 1*. The reverse *V-I* characteristic of a typical diode clipper is shown n *Fig. 2*. R_d is the impedance of the diode in the breakdown" region. The power dissipated is given by

$$P = I_0 E_0 + I^2_{rms} R_d \quad (1)$$

vhere I_0 is the average value of the current through he diode, and I_{rms} is the *rms* value of the same cur- ent. The first case to be considered is one in which he clipped voltage E_0, is relatively large and the breakdown" region sharp. In this case the second term of Eq. (1), $(I^2_{rms} R_d)$, is much less than the first term, $(I_0 E_0)$, and may be neglected. Then

$$P = I_0 E_0 \quad (2)$$

Eq. (1) and (2) neglect the power dissipated in the liode due to the conduction before the "breakdown" egion, but in most cases, (especially in silicon diodes) his power is very small and may be neglected. If re- uired, it may be computed fairly easily and added o the final results. In order to solve Eq. (2), I_0 must e found.

$$I_0 = \frac{1}{\pi} \int_{\omega_o}^{\pi/2} \frac{E_p \sin \omega - E_0}{R + R_d} \, d\omega \quad (3)$$

vhere $$\omega_0 = \sin^{-1} \frac{E_0}{E_p}$$

$$I_0 = \frac{1}{\pi (R+R_d)} \left[-E_p \cos \omega - E_0 \omega \right]_{\omega_0}^{\pi/2}$$

but $$\sin^{-1} \frac{E_0}{E_p} = \cos^{-1} \sqrt{1 - \frac{E_0^2}{E_p^2}}$$

and $$\frac{\pi}{2} - \sin^{-1} x = \cos^{-1} x$$

and $$E_p = E_0 + I_p (R+R_d)$$

Therefore

$$I_0 = \frac{E_0}{\pi (R+R_d)} \left\{ \left[\frac{2 I_p (R+R_d)}{E_0} + \frac{I_p^2 (R+R_d)^2}{E_0^2} \right]^{\frac{1}{2}} - \cos^{-1} \frac{E_0}{E_0 + I_p (R+R_d)} \right\} \quad (4)$$

Setting $$M = \frac{I_p (R+R_d)}{E_0} \quad (5)$$

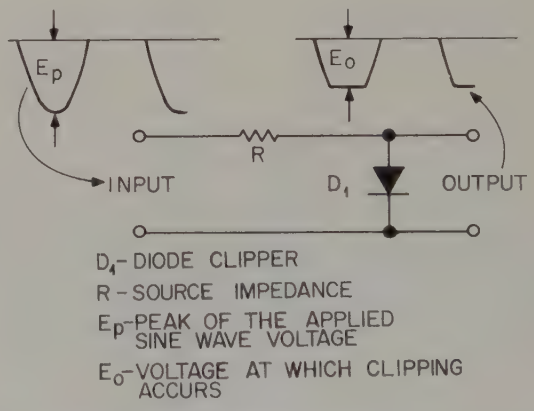

Fig. 1—Typical diode clipper circuit.

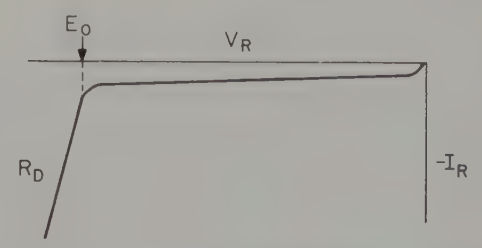

Fig. 2—Reverse V-I characteristic of a typical diode.

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The work presented here was done while Mr. Mitchell was associated with Raytheon Mfg. Co.

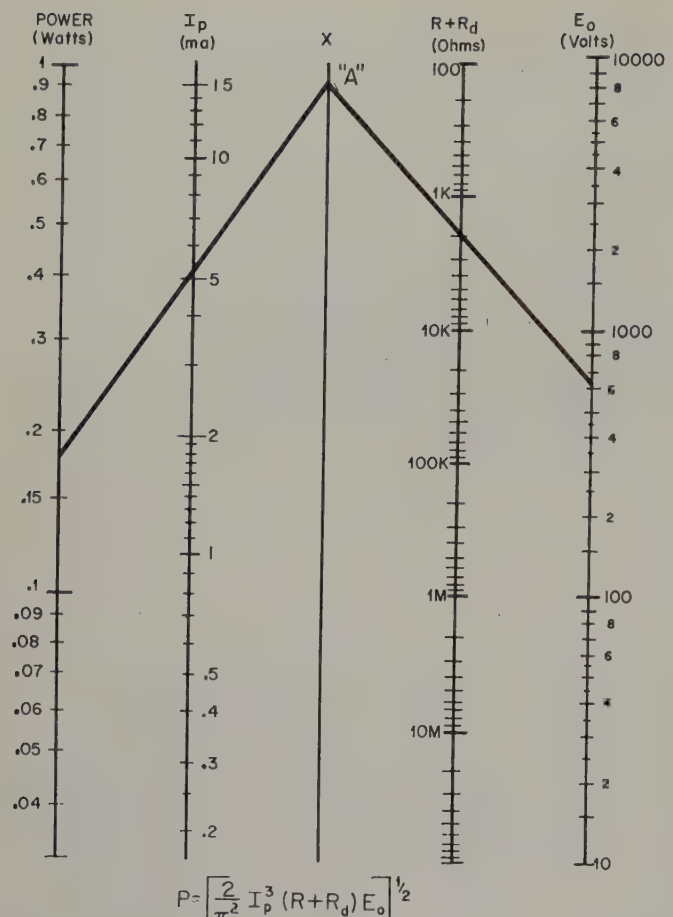


Fig. 3—Nomograph for determination of power dissipated in a diode clipper when conduction occurs during a small portion of the cycle. ($E_o \cong E_p$)

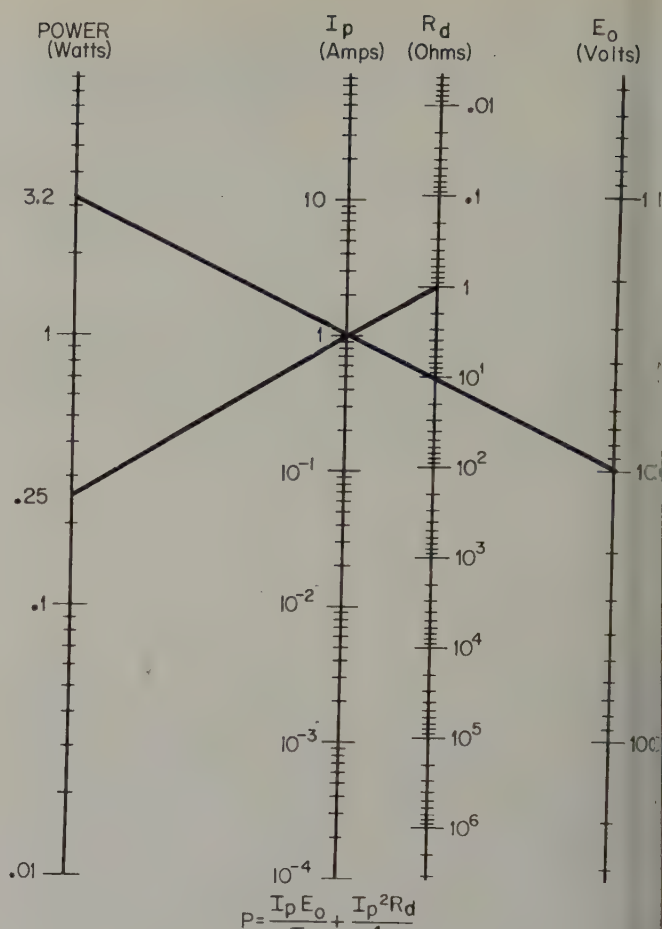


Fig. 4—Nomograph for determination of power dissipated in a diode clipper when conduction occurs during a large portion of the cycle. ($E_o \ll E_p$)

gives $$I_0 = \frac{I_p}{\pi M}\left[(2M+M^2)^{\frac{1}{2}} - \cos^{-1}\frac{1}{1+M}\right] \quad (6)$$

but $$\cos^{-1}\frac{1}{1+M} = \sin^{-1}\left(\frac{M^2+2M}{[M+1]^2}\right)^{\frac{1}{2}}$$

M is the ratio of the clipped voltage, $I_p\ (R + R_d)$, to the unclipped, or output voltage, E_0. If this value is very small, or in other words, if clipping occurs only during a very small portion of the cycle, then the sine of the angle may be replaced by the angle giving,

$$I_0 = \frac{I_p\,(2M + M^2)^{\frac{1}{2}}}{\pi\,(M+1)} \quad (7)$$

but since $M \ll 1$

$$I_0 = \frac{I_p\,(2M)^{\frac{1}{2}}}{\pi} \quad (8)$$

Substituting the value of M gives

$$I_0 = \left[\frac{2\,I_p^3\,(R+R_d)}{\pi^2\,E_0}\right]^{\frac{1}{2}} \quad (9)$$

and from Eq. (2)

$$P = I_0\,E_0 = \left[\frac{2}{\pi^2}\,I_p^3\,(R+R_d)\,E_0\right]^{\frac{1}{2}} \quad (10)$$

From the conditions set up, Eq. (10) will hold only when E_0 is very nearly equal to E_p. *Fig. 3* is a nomograph of Eq. (10).

As a sample problem, assume a diode with a "break" point, E_0, of 600 volts, connected in the circuit of *Fig. 1*, conducting a peak current of 5.0 mA with E_p equal to 610 volts. From this information,

$$(R+R_d) = 2000 \text{ ohms}$$

To find the power dissipated in the diode connect the 600 volt point on the E_0 scale to the 2000 ohm point on the $(R + R_d)$ scale and extend this line to intersect the "X" scale at point "A." Connect point "A" to the 5 mA point on the I_p scale and extend this line to the "P" scale. This intersects at $P = 0.17$ watts.

Conduction During a Large Portion of Cycle

The above covers the case of conduction during a very small portion of the cycle, but there are many cases in which the conduction occurs during a great majority of the cycle ($E_0 \ll E_p$). If this is the case, the current through the diode will be approximately a half sine wave in which,

$$I_0 = \frac{I_p}{\pi} \tag{11}$$

$$I_{rms} = \frac{I_p}{2} \tag{12}$$

From Eq. (1)

$$P = I_0 E_0 + I^2_{rms} R_d = \frac{I_p E_0}{\pi} + \frac{I_p^2 R_d}{4} \tag{13}$$

Equation (13) may be broken down into two parts

$$P = P_{dc} + P_{ac} \qquad \text{where} \quad P_{dc} = \frac{I_p E_0}{\pi} \tag{14}$$

$$\text{and} \qquad P_{ac} = \frac{I_p^2 R_d}{4}$$

Fig. 4 is a nomograph of Eq. (14). P_{dc} is obtained by connecting "E_0" to "I_p" and finding the intersection on the "P" scale. The P_{ac} is obtained by connecting "R_d" to "I_p" and finding the intersection on the "P" scale. The total power is then the sum of the two.

As an example, assume a 10 volt "Zener" diode connected in the circuit of *Fig. 1*. If I_p is 1 ampere, E_p 150 volts, and Z_d 1.0 ohms, then from the nomograph,

$$P_{dc} = 3.2 \text{ watts}$$

and $$P_{ac} = 0.25 \text{ watts}$$

and the total power is

$$P = P_{dc} + P_{ac} = 3.2 + 0.25 = 3.45 \text{ watts}.$$

It is interesting to note that the conditions of the second case also apply to an ordinary diode used as a rectifier. In this case, E_0 would be the "threshhold" of the diode, R_d the forward dynamic impedance of the diode and I_p the peak forward current. This will not be accurate for multiphase rectifier circuits in which Equations (11) and (12) are not true, but will hold for single phase circuits.

As an example, assume a silicon rectifier ($E_0 = 0.7$ volts), with a dynamic impedance of 0.1 ohm rectifying an average current of 5 amps.

Then $$I_p = \pi I_0 = 15.7 \text{ amps}$$

From the nomograph

$$P_{dc} = 3.5 \text{ watts}$$

and $$P_{ac} = 6.4 \text{ watts}$$

so that $$P = 9.9 \text{ watts}$$

At times it may be necessary to use cases one and two at the same time in computing the power dissipated in a diode. As an example assume a diode connected as shown in *Fig. 5*. If the characteristics of the diode are as shown in *Fig. 6* then in the reverse direction,

$$I_p = \frac{E_p - E_0}{R + R_d} = 9.1 \text{ mA}$$

From the nomograph in *Fig. 3*

$$P_{reverse} = 0.15 \text{ watts}$$

For the power dissipated in the forward direction, the second case applies.

$E_0 = 0.7$ volts

$R_d = 10$ ohms

$I_p = 148$ mA

$P_{dcforward} = 0.035$ watts

$P_{acforward} = 0.056$ watts

$P_{total} = 0.15 + 0.035 + 0.056 = 0.241$ watts.

Most diodes used today as clippers are either low voltage types or are regular diodes used in the forward direction. However as manufacturing techniques continue to improve, stable diodes will be readily available to be used as clippers up to many hundreds of volts and higher. By connecting diodes in series there will be no limit to the voltage which may be clipped.

The use of diode clippers in parallel requires the use of current equalizing resistors in series with each clipper. It is desirable to have the peak voltage drop across the resistor at least twice as much as the maximum variation in Zener voltages of the units.

For example, if a 10.0 volt and a 10.5 volt regulator are to be connected in parallel, the resistors should be chosen so as to have at least a 1.0 volt drop at I_p assuming that the current would split equally.

It will almost invariably turn out that a single clipper, with a higher current rating, will prove superior in regulation to two units in parallel.

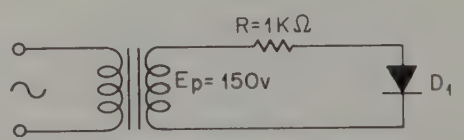


Fig. 5—Circuit which requires consideration of both long and short duty cycles.

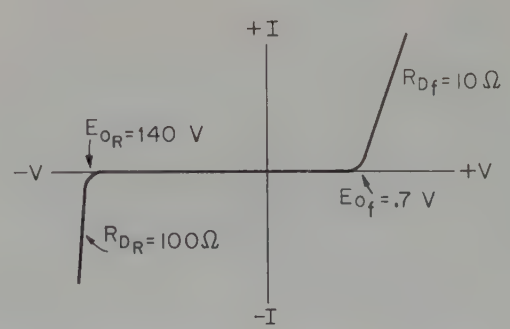


Fig. 6—Characteristic of diode used in Fig. 5.

INDUSTRY REPORT

MATERIALS and MACHINERY USED in the SEMICONDUCTOR INDUSTRY

From data supplied to us by Manufacturers and Users in an industry-wide survey

[Tear sheets of this report are available on written request]

THIS REPORT, compiled by the marketing department of SEMICONDUCTOR PRODUCTS Magazine, was made possible through the cooperation of the semiconductor device manufacturers' purchasing and public relations offices. It is intended as a marketing guide to the materials and machinery manufacturers serving the semiconductor industry so that they might utilize their facilities for the growth of the semiconductor industry.

Although it was obviously impossible to acquire information from every device manufacturer, a large enough cross-section of the industry was covered to make this survey applicable to the industry as a whole. Our marketing staff estimates that those manufacturers who provided us with statistics make and sell upwards of 50% of all semiconductors devices on the open market.

Germanium—The largest primary material used in the semiconductor industry, germanium is used by more than 85% of the device manufacturers. The largest independent supplier is Eagle-Picher, while the Chemical and Metallurgical division of Sylvania has cornered an almost equally large share of the market. American Metal Climax appears to rank third in this field.

Other suppliers listed, although not to any great extent, are African Metals Corp., American Zinc, and Semimetals.

Silicon—Although not used by as many manufacturers as germanium, silicon is the next largest single material used by the semiconductor industry. The largest single silicon supplier is DuPont, although both Merck and Texas Instruments have made sufficient inroads to offer a serious threat to DuPont's No. 1 position. It must be noted that Merck, like DuPont, is an independent supplier while Texas Instruments is the largest semiconductor device manufacturer and as such, uses a large percentage of the silicon it produces for its own needs. Knapic Electro-Physics and Grace are other independent factors in growing contention.

Several device manufacturers have chemical divisions supplying their own needs with sufficient quantities remaining as a source to the industry. Besides Texas Instruments, already mentioned, Sylvania appears to be the largest in this category. Trancoa (division of Transitron) is also making headway in the silicon field.

Other silicon suppliers to the industry include Eagle-Picher, Mallinckrodt, and Allegheny Electronic Chemical.

It must be noted that some manufacturers use raw silicon, growing their own crystals, while others buy ready-grown crystals from the above-mentioned suppliers.

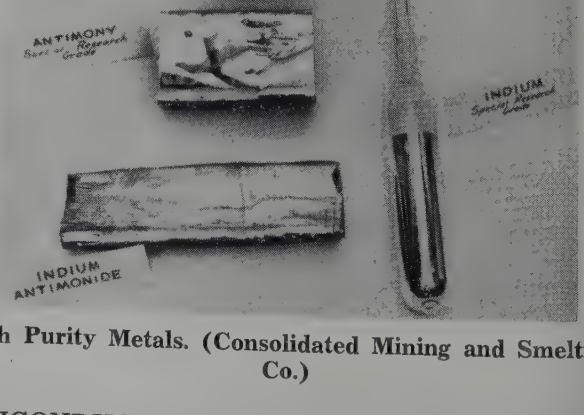
Chemicals—Because several dozen types of chemicals are used by the semiconductor industry, the average device manufacturer uses more than one supplier to meet all his needs. The largest single supplier appears to be Allied Chemical Corp. with at least 25% of the total volume. A close second is J. T. Baker while DuPont, Mallinckrodt, Dow Corning, and Fisher Scientific all do large volume business in the field. Many other names are also mentioned, including Dow & Ingalls, Howe & French, Merck, Raffi & Swanson, M. E. Baker, Chemical Compound, American Scientific, Crane Packing, and Acme Donnerman.

Quartz—Next to raw silicon and germanium, the most essential material in the growing of crystals is quartz. This market has been captured by two major suppliers, General Electric and Amersil division of Englehard Industries, who share more than 90% of the volume.

Other suppliers mentioned were P. W. Blackburn, Syncor Products, Corning Glass, and Thermal-American Fused Quartz Co.

Carbon Products—Including graphite boats, jugs and other accessories, carbon products play an important part in refining raw materials for transistor and diode production. The largest single supplier is United Carbon Products Company, with National Carbon and Pure Carbon Company also getting a major portion of the total volume. Others mentioned were: Speer Carbon, Textool Products, Ohio Carbon and Stackpole.

Alloys—An important factor in the semiconductor industry, the various precious metals and alloys are the most difficult segment to pinpoint in-



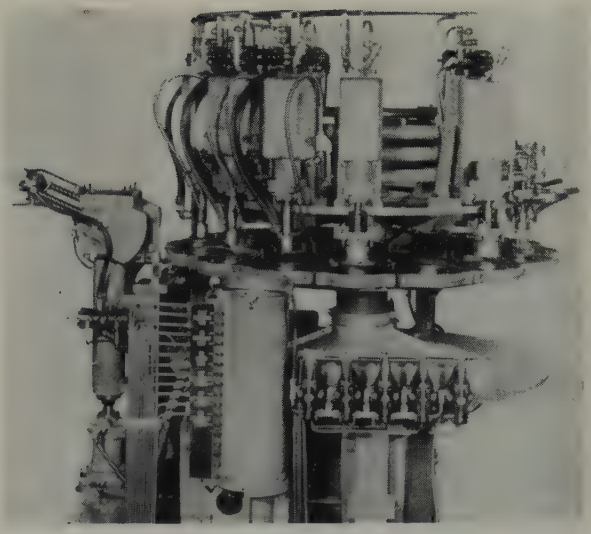
High Purity Metals. (Consolidated Mining and Smelting Co.)

Semiconductor Alloy Kit. (Accurate Specialties)

sofar as volume or relative position is concerned, since many manufacturers list several suppliers, and since many different types are used for different applications.

Several names appear as major factors in the industry, including Sigmund Cohn, Inc., Accurate Specialties, Alpha Metals, Alloys Unlimited, Metals & Controls (division of Texas Instruments), Indium Corp. of America, and Anchor Metals. Other names, getting a small segment of the business include Handy & Harmon, Cominco, Goldsmith Brothers, American Silver, and Research Instrument Corp.

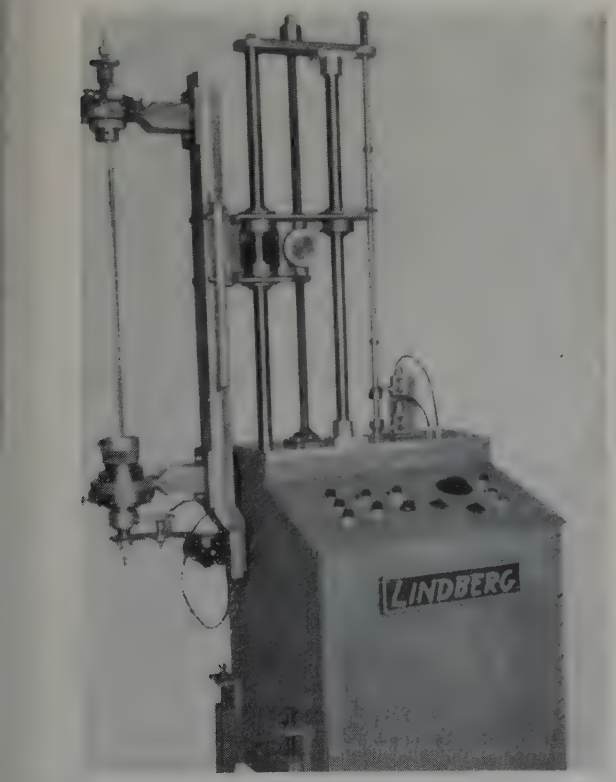
Crystal-Growing Equipment—Only about half the device manufacturers grow their own crystals, the vast majority of these indicating that they make their own machinery for the purpose. Of the independent manufacturers listed, Kahle Engineering and National Research Corp. share the great bulk of this specialized business.



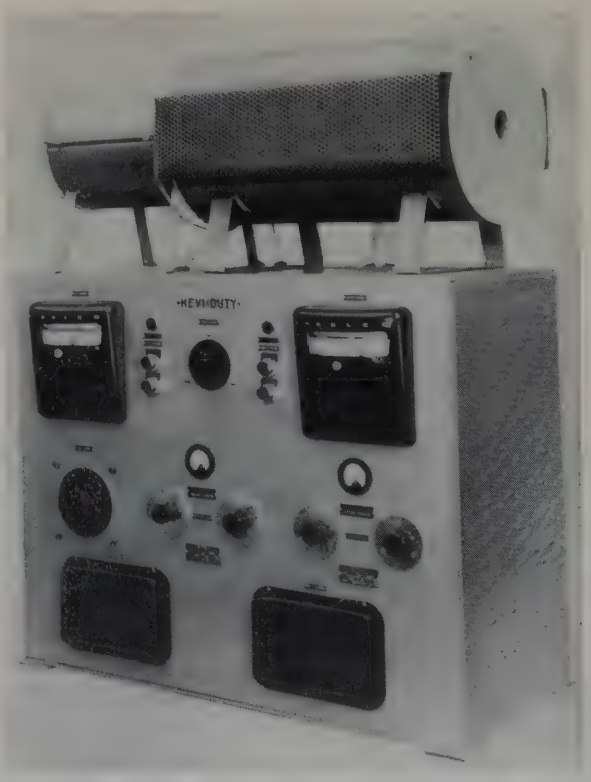
Automatic Hole Puncher and Fire Glazer. (Kahle Engineering Co.)

Wafering Machinery—Micromech Manufacturing stands out as the largest single supplier of this equipment to the semiconductor industry. Several device manufacturers have developed their own equipment. Others have obtained wafering machinery from Doall Co., Reid Brothers, P. R. Hoffman, Brown & Sharpe, Felker, Nichols, Raytheon, and U. S. Burke.

Furnaces—Used in very large quantities by the entire industry, with virtually no exception. The major names that stand out in this field are Hevi-Duty, BTU Engineering and Blue M Electric, with Lindbergh and American Electric Furnace also getting a substantial volume of business. These companies



Floating Zone Scanner. (Lindberg Engineering Co.)



Two Zone High Heat Furnace. (Hevi-Duty)

probably share more than 75% of the total volume.

Other firms listed include: Stewart, C. I. Hayes, General Electric, C & M Manufacturing, Hoskins, Precision Instruments, Sandland Tool Co., and Sargeant & Wilbur.

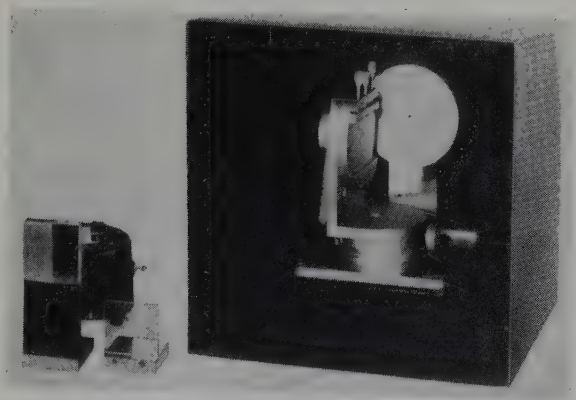
Welding Equipment—One name stands out as the obvious leader in the welding field, that of Ray-

Ultrasonic Welder for Ohmic Contacts. (Sonobond Corp.)

theon, who appear to get more than 30% of the total volume. Other names showed up with some regularity, including Federal Tool, Weldmatik division of Unitek, Taylor-Winfield, Federal Machine & Welder and Thompson Products. These four companies share about 60% of the market with Taylor-Winfield probably ranking second in the field.

Others mentioned were Precision Welder and Flexopress, Carter Welding, Thomson Electric, and Sonobond Corp., (Division of Aero Projects).

Orientation Systems—Used by only about half the manufacturers in the industry as yet, these



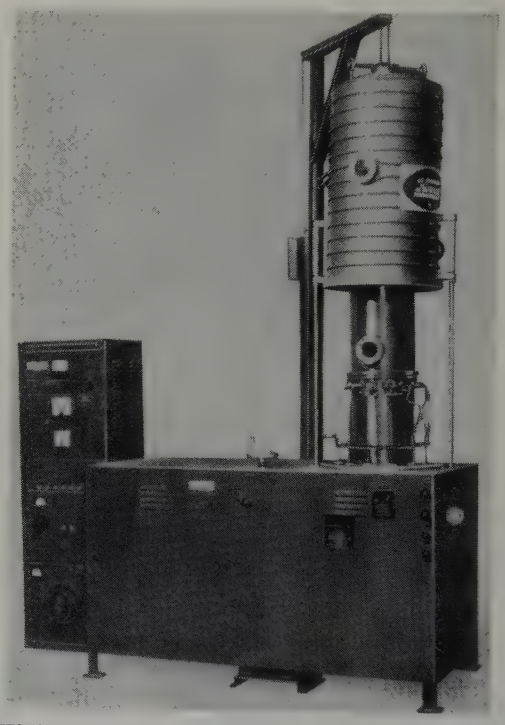
Orientation System. (Micromech Mfg. Co.)

systems have been obtained from Micromech, Sylvania, Syntron, and North American Phillips.

Microscopes—Used in very large quantities, not only in research, but on the production line as well, microscopes represent an important factor in the production of semiconductor devices. Our survey indicates that American Optical is the largest single supplier in the field with almost 50% of the volume; Bausch & Lomb is a close second with close to 45%. Leitz, Zeis, and Doall were also mentioned.

Vacuum Pumps—This equipment is used in large quantities by most manufacturers in the industry. Although many names are well-known in the field, the companies getting the largest volume of the business are Kinney (division of New York Air Brake), Welch Manufacturing, and NRC Equip. Co.

Others listed are: F. J. Stokes, Veeco, Consolidated Electrodynamics, High Vacuum Equipment Corp.,



Ultra High Vacuum Unit. (Kinney Div., N.Y. Air Brake Co.)

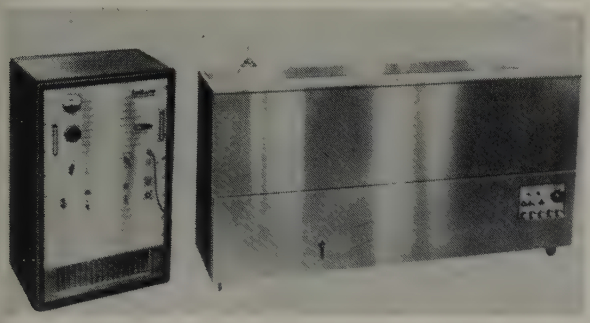
Gast Manufacturing, Central Scientific, Duo-Seal, and Ajax Air Compression.

Wire and Leads—Here again, a great many names appear in the survey returns. Our staff estimates that Sigmund Cohn Inc. and Art Wire are neck and neck for the leadership in this category, with Sylvania, Driver-Harris, Pix Manufacturing and Wilbur H. Driver strong contenders.

Other names mentioned were S. Burger, Stewart Stamping, Fryling Manufacturing, General Electric, Philadelphia Insulated Wire, Flexo Division of Copperweld, Nesor Alloy, American Super-temp, Stanley Humason, and Sweet Manufacturing.

Seals and Enclosures—It was absolutely impossible to collate the material on this category to come up with any real estimate of who are major factors in the business. The average device manufacturer uses from 4 to 7 different suppliers, and the names were so varied as to make it impossible to get a substantial market analysis.

Ultrasonic-Cleaning Equipment—A section of the industry that's relatively as young as the semiconductor industry itself, ultrasonics is making tremendous strides with device manufacturers. At

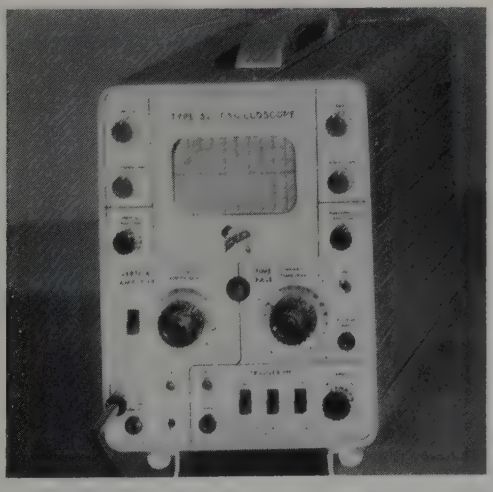


Ultrasonic Generator and Transducerized Tank. (Narda Ultrasonics Corp.)

least 85% of the industry is currently using this equipment. Our figures indicate that Narda is the largest single supplier with about 40% of the business. Acoustica and Branson apparently share the next 50%, with L & R, Sheffield, Arenburg and Pioneer-Central Division of Bendix getting occasional mention.

Environmental Test Chambers—This equipment, primarily used by the larger device manufacturers, can be found in various forms, and sizes for different applications. The leader in the field is Tenney Engineering, with Webber, International Radiant, General Testing Labs, Associated Testing Labs, Statham, and All American Tool also mentioned. In a few instances, the device manufacturers build their own equipment.

Test Instruments—The broad nature of this category and the many different types of equipment used makes it a tricky segment to analyze. However, several names stand out with repeated mention, including Tektronix, Hewlett-Packard, Baird-Atomics,



Transistorized Battery Operated Portable Oscilloscope. (Tektronix, Inc.)

Ballentine, General Radio, Dumont, North Hills, and General Electric.

Other suppliers, far too numerous to include, number in the dozens.

Dry Boxes—About half the manufacturers in the semiconductor industry have developed their own dry boxes. Of those who purchase from an independent source, the great majority have bought from Temperature Engineering Corp. with some volume also going to Cox Engineering, The Baker Co., and Kewannee Mfg.

Ultrasonic Cutting Tools—Again, the field of ultrasonics has made great inroads with the semiconductor industry. More than 90% of the manufacturers surveyed are presently using this equipment. Only two manufacturers are major factors in the field. These are Raytheon and Sheffield division of Bendix Aviation. Pioneer-Central division of Bendix also is in this field.

Micromanipulators—Used to very little extent, according to the survey.

Marking Machinery—Used extensively throughout the industry. The greatest bulk of the business goes to Markhem Machinery Company which gets better than 70% of total volume. Second in rank would be Popper, with New Hermes, Rejafix, and Matthews, mentioned.

Glass Beading Machines—Used in producing glass diodes and other types of specialized semiconductors, this is a specialty item that many manufacturers cannot yet use. The only significant factor in this field is Kahle Engineering.

Ceramics—With a great variety of applications in the industry, various types of ceramics and ceramic products are used by more than 30% of device manufacturers. The largest single supplier seems to be American Lava Corp. Other major manufacturers include General Ceramics, Coors Porcelain, Carborundum, and Raytheon. Others listed were: McDaniel Refracting, Frenchtown Porcelain, Miltronics, Ceramic Metal Assemblies Corp., Advanced Vacuum Products, and Ceramics for Industry.

Epoxy Resins—These are used quite extensively in the potting or sealing of semiconductor devices. Our survey returns indicate that Epoxy Products Company and Minnesota Mining & Manufacturing are the two predominant suppliers to the industry. Emerson & Cuming, Dow Corning, Houghton Laboratories, Duramic, and Electronics Plastics Corp., were also mentioned.

The materials and types of equipment listed above are the major components used by the semiconductor manufacturers. Obviously, there are many other types used by a particular producer for a special project or purpose. However, these are, in the opinion of our staff, too insignificant in total volume to consider for an industry analysis.

We wish to thank the purchasing agents, advertising and public relations managers, sales personnel and other marketing executives at the many semiconductor device manufacturing firms, without whose aid this market study would not have been possible.

APPLICATIONS ENGINEERING DIGESTS

For further information circle the Reader Service Card number of the desired application note on the inquiry card provided at the back of the magazine.

APPLICATIONS ENGINEERING DIGEST NO. 16

Video Amplifier (20 cps to 7 mc); Transitron Electronic Corp., Wakefield, Mass.

The use of the new Transitron 2N1139 high frequency transistor makes possible a simple video amplifier with a minimum of components. No inductances are used, and the only capacitors used are for coupling between stages. No neutralization is needed as the circuit is extremely stable and shows no tendency toward oscillation. The equivalent input noise current over the entire band width is typically less than 0.02 μA *rms* with unselected 2N1139's.

The circuit is so designed that individual transistor parameters are almost insignificant, and wide variation in units gives negligible change in circuit operation and response.

This video amplifier utilizes two doublet stages with inverse feedback around each doublet. In each doublet, the short circuit current gain, B', is given by,

$$\frac{1}{B'} \cong \frac{1}{B_1 B_2} + \frac{R_1}{R_2}$$

where B_1 and B_2 are the betas of the individual transistors at the specified frequency.

If $B_1 B_2$ is large compared to $\frac{R_2}{R_1}$, then

$$B' \cong \frac{R_2}{R_1}$$

In this circuit $\frac{R_2}{R_1} = 20$, thus as long as $B_1 B_2 >> 20$, the gain of each doublet will be 20, and the total gain will be 400.

In addition, there is a coupling loss between doublets, and at the input, of approximately 1 *db* near the high frequency limit. This is primarily due to the increase in input impedance caused by the decrease of degenerative feedback. This effect is a limitation of high frequencies.

The output impedance is 1000 ohms shunted by approximately 100 mmfd at 10 *mc*. (10 mmfd x B_2). This explains the more rapid roll off at high values of R_L.

The low frequency response is limited only by the coupling capacitors, since the doublets are flat to *d-c*. With the 60 mfd capacitors used, the *3db* point is about 20 *cps* with R_L = 10 to 1000 ohms.

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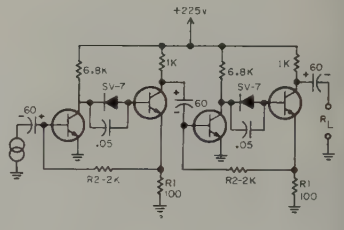

Fig. 16.1—Video amplifier with two doublets.

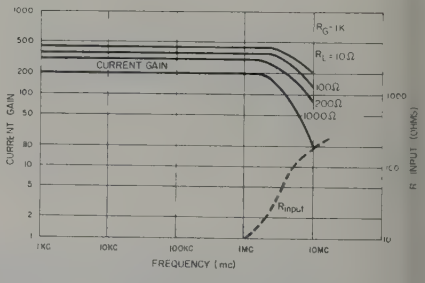

Fig. 16.2—Video amplifier frequency response.

APPLICATIONS ENGINEERING DIGEST NO. 17

A Survey of Some Basic Trigistor Circuits; Solid State Products Inc., Salem, Mass.

The electronics industry is now entering a new phase of the well established "Solid State Era." This new phase, sometimes referred to as "Molecular Electronics" involves the use of new semiconductor components which can perform the function of partial or complete electronic circuits. These new components are called "Circuit Equivalent" or "Circuit Function" components.

The first commercially available version of a "Circuit Equivalent" component with characteristics comparable to a flip-flop or bistable multivibrator is the Silicon Trigistor. (Pronounced Trigistor and derived from triggered bistable transistor.) Developed by Solid State Products, Inc. of Salem, Mass., the Trigistor represents a significant advance in semiconductor technology.

The problem of achieving ultimate size reduction while at the same time maintaining high reliability in electronic systems can only be really solved by fundamental simplification of the individual circuits comprising the system. The "circuit equivalent" semiconductor components offer the means for achieving basic circuit simplification. In addition they possess the same basic reliability now commonly acknowledged for the transistor.

One Shot Multivibrator

Figure 17.1 shows a one shot multivibrator or delayed pulse generator which can provide accurate timing for delay times up to 10 seconds. The Trigistor's characteristics have only a small effect on timing, and accuracy is determined essentially by the stability of the timing capacitor, and supply voltage. The circuit as shown will provide a 1 second rectangular pulse output.

With the circuit in its quiescent condition, the Trigistor is "on." Point *B* is at +1 volt, and point *A* is at —11 volts due to the voltage divider action of R_1, R_2, R_3 and the 5 volt zener diode. The 1N482A is in the reverse direction. R_4 and R_5 provide bias stabilization.

When a negative trigger pulse is applied to the input, the Trigistor is turned *off*. Point *B* rises to approximately +30 volts and *C* begins to charge toward a positive voltage through R_1 and the zener diode. When point *A* reaches +1.5 volts, D_1 conducts and the Trigistor turns *on*, bringing point *B* back to +1 volt. *C* then charges through R_3 back to its quiescent voltage of —11 volts.

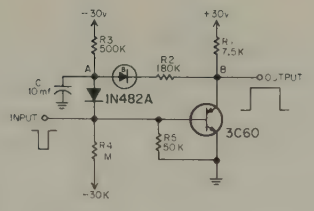

Fig. 17.1—One-shot multivibrator.

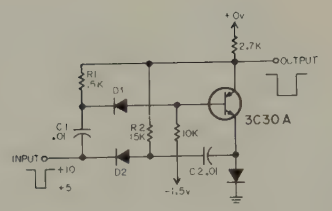

Fig. 17.2—Flip-flop binary counter

Flip Flop Binary Counter

A flip-flop for binary counting is shown in *Fig. 17.2*. This circuit is a 2:1 binary divider operating on negative trigger pulses. A trigger pulse steering network has been added to the basic circuit to obtain this counter circuit. Diodes D_1 and D_2 act as gates while R_1, R_2, C_1 and C_2 provide gating bias.

If the Trigistor is "off," point *A* is at +10V and C_2 is charged to +10V. C_1 remains uncharged. When a negative pulse occurs at the input, D_2 conducts and couples the pulse to the emitter which turns the Trigistor on. Since C_1 is uncharged, point *B* drops from +10 to +1 volt when the trigger pulse is applied. D_1 remains reverse biased and the trigger pulse is blocked from the base.

With the Trigistor "on," points *A*, *B* and *C* are all at +1V. When the next negative input pulse occurs, D_1 goes in the forward direction coupling the pulse to the base and turning off the Trigistor. D_2 remains reverse biased and blocks the pulse from the emitter.

The input of this circuit is ideally driven from the collector of an identical Trigistor flip-flop or from the collector of an *n-p-n* silicon transistor. Connecting many counter stages in cascade is therefore quite simply accomplished.

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APPLICATIONS ENGINEERING DIGEST NO. 18

VHF Tuner—Channels 3, 6, 10, and 13; by J. Specialny, Lansdale Tube Co., Lansdale, Pa.

This report contains data taken in a series of measurements of the MADT's in an experimental *vhf* tuner. The object of this investigation was to construct a suitable tuner employing MADT's in the three sockets, (*rf* amplifier, *rf* mixer, and local oscillator.) The tuner is of the turret type and originally had used tubes to perform the necessary functions. Besides the basic application to *vhf* TV receivers, this tuner can be also readily adapted for uses in *vhf* communications and *fm* receivers by proper modification of the tuning elements.

Circuit Description (Fig. 18.1)

The input impedance of the tuner presently is about 50 ohms. A common base *rf* amplifier, TR1, with neutralization, is employed in the first socket. A common emitter connection is utilized for the mixer, TR2, and the local oscillator injection is applied to its base. Also, a series trap tuned to 44 *mc* is inserted from mixer base to ground. TR3 is a common base oscillator and provides the necessary injection power. The output of the mixer is tuned to 44 *mc* by transformer *T1* and is terminated in a 50 ohm load.

Conclusions

Tests indicate that an all transistorized tuner is feasible with overall gains of about 24 *db* at Channel 13 to 35 *db* of Channel 3. The *if* response has a band width which is generally considered adequate.

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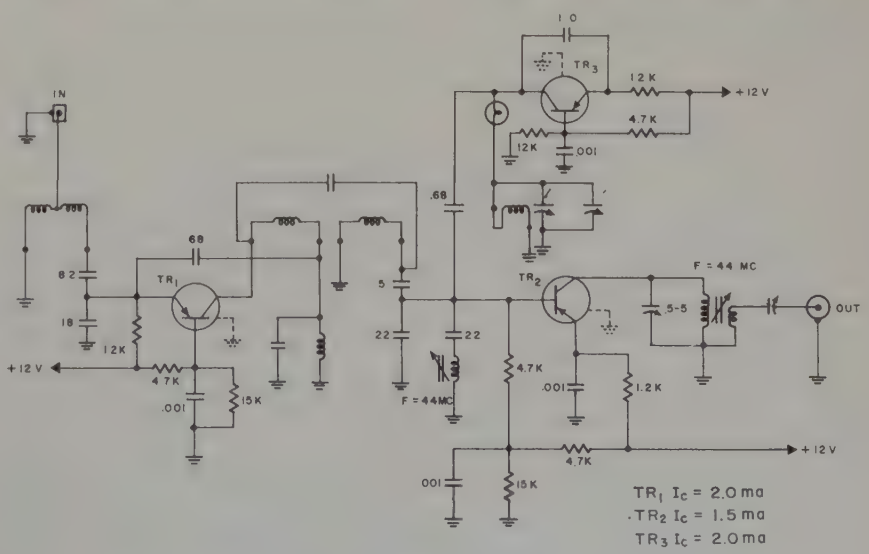

Fig. 18.1—VHF tuner circuit.

APPLICATIONS ENGINEERING DIGESTS NO. 19

Mercury Relay Pulse Generator; by R. Carney, Lansdale Tube Co., Lansdale, Pa.

This digest describes a pulse generator capable of providing narrow pulses having rise and fall times of only fractional parts of a millimicrosecond. The principal use of this generator is intended for use in testing *MADT* pulse circuits. A number of generator circuits were attempted, but the one shown in *Fig. 19.1* proved to be the most satisfactory.

Generator Circuit and Performance

With the battery polarity as shown, the circuit feeds a positive pulse 500 millimicroseconds wide to the two output terminals with each closure of S_1, which by virtue of its relay-control occurs 60 times a second. The coaxial delay line is used basically as a capacitor. It is charged through R_2 during the time S_1 is open. When S_1 closes, the discharge of the line through R_3 and/or the input circuit of the driven stage provides the output pulse. R_3 is normally set to provide an output load, R_o, equal to the surge impedance, Z_o, of the line. In this case, the amplitude of the output pulse will equal half of V_1, with V_1 in turn being determined by the adjustment of the R_1 potentiometer.

The sharp pulse edges are obtained by the use of a mercury-relay contact for S_1 and by virtue of the *vhf* capabilities of the coaxial line. Square pulses are generated with rise and fall times less than 1 millimicrosecond, as observed on an EG & G Traveling Wave Oscilloscope Type 2236. Although reasonably clean, a certain amount of grass does exist around the pulse feet due to excitation of stray *LC* loops. Also, because the delay line introduces resistance losses of its own, the top of each pulse slants slightly downward toward its lagging edge.

R_2 is essentially an open circuit insofar as the pulse interval is concerned,

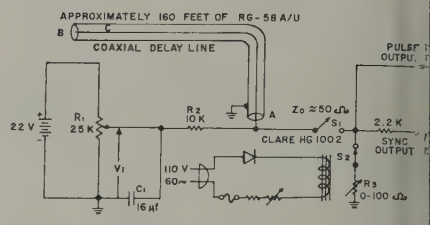

Fig. 19.1—Mercury relay pulse generator having a delay-line pulse former.

permitting a positive bias across the output of only 50 parts in 10,000. In operation, R_3 ($\approx R_o$) is normally adjusted to match the 50 ohm Z_o, thereby eliminating the possibility of a trailing pulse train. S_2 is not a part of the actual circuit as now constructed, but is shown to represent the fact that R_3 must be disconnected when the impedance of the driver stage is itself 50 ohms.

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APPLICATIONS ENGINEERING DIGEST NO. 20

Heat Sink Configurations Providing Thermal Resistances Between 10 and 50°C/watt; by J. Hiltebeitel, Lansdale, Pa.

This report describes and evaluates various heat sink configurations for power transistors that would lend themselves to printed circuit mounting and afford minimum space requirements. Four general heat sink configurations, both painted and unpainted, were investigated for thermal resistance properties. The measuring device had no provision for keeping the transistors and their heat sinks in upright or uniform positions; this may have had some effect on their radiation properties.

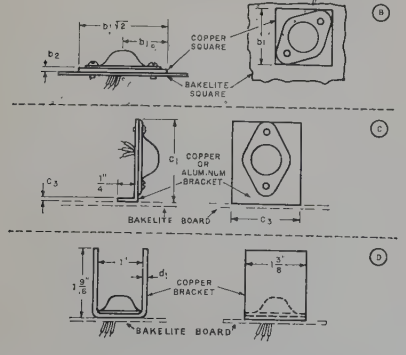

Fig. 20.1—Dimensions and mountings of the four groups.

The four general configurations that were used are described as follows (group (a) and (b) were mounted on 2 x 2 x 1/16 inch bakelite squares to simulate the printed circuit board):

(a) Aluminum candy wrappers with transistors mounted in the cups.
(b) Copper squares to simulate "printed" heat sinks.
(c) Copper and aluminum brackets for vertical mounting.
(d) Copper and aluminum "U"-shaped brackets.

Figure 20.1 gives the dimensioning and mounting data on these four groups.

At first it was intended that all sinks should have identical, centrally-located holes for the transistor leads, but this idea was discarded in favor of smaller holes, positioned for the transistor leads, because greater heat conduction would be afforded by additional contact with the base.

It would have been desirable to know the thermal resistance of each 2N353 transistor before mounting to determine the actual value of the different heat sinks. However, previous data has indicated that this is reasonably constant for a given transistor type.

The U-shaped sinks (group d) showed the best performance, followed by the vertical brackets, (group c). The performance of the squares, (group b), which overlapped somewhat into group c was equalled by the painted candy wrappers (group a).

Conclusions

(1) Material thickness, within the limits of our investigation, is of little significance.
(2) Maximum contact with the transistor base is important.
(3) Maximum exposed surface area is the biggest factor, as expected.
(4) Painting of sinks and transistor caps results in as much as a 30 to 40% decrease in thermal resistance.

Circle 197 on Reader Service Card

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Direct Measurement of the Angular Dependence of the Imaginary Part of the Atomic Scattering of Germanium	IBM Jl of Res & Dev April 1959	This paper describes the measurement of the rates of significant factors for several different sets of planes in nearly perfect germanium crystals.	L. P. Hunter
A Brief Survey of Direct Energy Conversion Devices for Possible Space-Vehicle Application	IRE Trans Mil Elec April 1959	Devices for converting heat or radiant energy into electrical form include thermoelectric generator, photovoltaic cell, thermionic converter and photoemissive converter.	A. E. Von Doenhoff D. A. Premo
A New Era in Communications Through Transistors	IRE Trans Vehic Comm April 1959	Answers to some of the early problems have been found. Description of commercial products.	W. W. Weisz
Bias Considerations in Transistor Applications to Communications Circuitry	IRE Trans Vehic Comm April 1959	Analysis takes into consideration power dissipation, temperature range, and values of resistors used to establish the bias potential.	A. G. Manke
Transistorized Power Supplies for Higher Input Voltages	IRE Trans Vehic Comm April 1959	Applications of switching transistors in the design of power supplies.	L. S. Pearlman
A Transistorized Selector Device for Bell System Mobile Telephone	IRE Trans Vehic Comm April 1959	Present day system used to individually call vehicles equipped for mobile telephone service is described.	W. G. Chaney
Selective Signaling in the Bell System—Relay to Transistor	IRE Trans Vehic Comm April 1959	Selector can also function as a basic element of a fully automatic mobile dial telephone system.	J. R. Scantlin
Dislocation Planes in Semiconductors	Jl App Phys April 1959	These are discussed from the point of view of their influence on carrier transport.	H. F. Matare
Distribution Coefficients and Carrier Mobilities in In Sb	Jl App Phys April 1959	The following distribution coefficients have been measured: Cd, 0.26; Zn, 3.38; Se, 0.17; and Te, 0.54.	A. J. Strauss
Contact Potential Measurements on Cleaned Germanium Surfaces	Jl App Phys April 1959	The contact potential was measured in a vacuum of less 10^{-9}mm Hg using a Kelvin bridge technique.	A. B. Fowler

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHOR
Capacitance and Barrier Height in Grain Boundaries	Jl App Phys April 1959	It is shown that the capacitance of a grain boundary depends on the height of the potential barrier O only if O is smaller than 2 kT in (Nd/n_1) (ev)	R. K. Mueller
Elastic Moduli of Single-Crystal Gallium Arsenide	Jl App Phys April 1959	Velocities of propagation of high-frequency ultrasonic waves and the adiabatic elastic moduli for single-crystal gallium arsenide are reported	T. B. Bateman H. J. McSkimin J. M. Whelan
Ohmic Aluminum-n-Type Silicon Contact	Jl App Phys April 1959	A method of making an alloyed contact to n-type silicon using aluminum has been developed	S. L. Matlow E. L. Ralph
X-Ray Integrated Intensity of Germanium Effect of Dislocations and Chemical Impurities	Jl App Phys April 1959	The absolute values were measure with CuK_α radiation.	B. W. Batterman
Measurements of the Dember Potential in Bulk Germanium	Jl App Phys April 1959	The potential difference which arises from a gradient of excess carrier density has been observed.	L. Stubbe B. Gossick
Growth of Silicon Crystal Free from Dislocations	Jl Phys Soc Jap April 1959	Sources of dislocations which are important at particular stages of growth are isolated and means found to minimize or eliminate them.	W. C. Dash
The General Theory of Transport; the Difference Between Electric Field and Density Gradient	Jl Phys Soc Jap April 1959	The difference between electric currents due to the external electric field and the gradient of the chemical potential is discussed.	T. Kasuya
Crystal Structure of Sodium-Potassium Antimonide (Na_2KSb)	Phillips Res Rep April 1959	X-Ray analysis of Na_2KSb, a photoemissive material, has led to the determination of its crystal structure.	J. J. Scheer P. Zalm
Diffusion Capacitance in Transistors	Phillips Res Rep April 1, 1959	Calculations of the diffusion capacitance (injection or storage capacitance) have been carried out taking into account the influence of the second junction.	K. Boke J. B. M. Spaapen N. B. Speyer
Three-Dimensional Electric-Circuit Model of the High-Frequency Phenomena in a Junction Transistor	Phillips Res Report April 1959	The linearized problem, corresponding to small-signal operation of the transistor, may be solved with the aid of an electric-circuit model.	G. Brouwer
Acoustoelectric Effect in n-Type Germanium	Physical Review April 1, 1959	Theory and experiment are presented for the drag exerted on electrons in a solid by a traveling ultrasonic wave.	G. Weinreich T. M. Sanders Jr H. G. White
Infrared Absorption and Electron Effective Mass in n-type Gallium Arsenide	Physical Review April 1, 1959	The infrared absorption between 0.85 and 25 microns has been measured as a function of carrier concentrations for this material.	W. G. Spitzer J. M. Whelan
Exciton and Magneto-Absorption of the Direct and Indirect Transitions in Germanium	Physical Review April 1, 1959	Experiments on magneto-absorption effects in germanium have resolved fine structure in the direct interband transition, and have revealed structure in the indirect transition.	S. Zwerdling B. Lax L. M. Roth K. J. Button
Theory of Optical Magneto-Absorption Effects in Semiconductors	Physical Review April 1, 1959	The theory of the effect of a magnetic field on the optical absorption in semiconductors is developed on the basis of the effective-mass transformation.	L. M. Roth B. Lax S. Zwerdling
Slow Capture of Holes and Electrons by Surface States on Germanium and Silicon at Low Temperatures	Physical Review April 15, 1959	Field-effect decay curves at liquid nitrogen temperatures are presented for n- and p-type germanium, and for p-type silicon.	S. R. Morrison
Lattice Specific Heats Near O°K with an Application to Germanium	Physical Review April 15, 1959	Formulas are developed on the basis of the general adiabatic and harmonic assumptions independently of special models or numerical procedures.	P. M. Marcus A. J. Kennedy
Microwave Field Dependence of Drift Mobility in Germanium	Physical Review April 15, 1959	Electrons and holes in germanium have been treated by microwaves with an extension of high microwave fields of the technique developed by Morgan.	K. Seeger
Ordinary Hall Effect in Fe_3O_4 and (NiO) 0.75 (FeO) 0.25 (FE_2O_3) at Room Temperature	Physical Review April 15, 1959	The ordinary Hall-measurements of Fe_3O_4 suggests that the number of conduction electrons at room temperature is of the order of $3x10^{21}/cm^3$.	J. M. Lavine
Calculation of the Photoconductivity from A.C. Impedance Changes induced in ZnS and ZnCdS Phosphors	Phys & Chem of Sol April 1959	To determine the true induced conductivity of ZnCdS-type phosphors, *a.c.* impedance measurements are required so that the barrier effects of the grains and electrodes can be eliminated.	H. Kallmann B. Kramer P. Mark
Infrared Absorptions in Zinc Oxide Crystals	Phys & Chem of Sol April 1959	Optical absorption in the 1-12 μ region has been observed in single crystals of ZuO at 300°K and 78°K.	D. G. Thomas
Electron Paramagnetic Resonance in Single Crystals of $BaTiO_3$	Phys & Chem of Sol April 1959	The paramagnetic resonance of an impurity in single crystals of $BaTiO_3$ has been studied.	A. W. Hornig R. C. Rempel H. E. Weaver
Pressure-Dependence of the Resistivity of Germanium	Phys & Chem of Sol April 1959	The effect of hydrastatic pressure has been investigated up to 2700 atm at temperatures between 125 and —125°C.	A. Michels J. Van Eck S. Jachlup C. A. Ten Seldam
A Tubeless Industrial Telemeter of the Frequency Type	Power App & Syst April 1959	System designed for high component and circuit reliability to withstand extremes in environmental conditions.	D. E. Kotas J. Parnell
A New Concept in Computing	Proc IRE April 1959	The concept of using the phase of a sine-wave signal as an information-bearing medium which together with majority logic permits the realization of logic operation.	R. L. Wigington
Stored Charge Method of Transistor Base Transit Analysis	Proc IRE April 1959	A base layer transit time analysis has been made for high-frequency transistor base donor distributions.	L. J. Varnerin
The Hall Effect Circulator—a passive Transmission Device	Proc IRE April 1959	Description and analysis of the Hall Effect circulator, a 3-port (6-terminal) nonreciprocal passive device.	W. J. Grubbs
Theory and Experiments on Shot Noise in Silicon P-N Junction Diodes and Transistors	Proc IRE April 1959	New theoretical expressions are derived on the basis of recombination-generation in the depletion layer.	B. Schneider M. J. O. Strutt
Some Optical Characteristics of Semiconductors	Res App in Ind (Br) April 1959	Optical absorption of semiconductors can give a wealth of information about the electronic structure of perfect crystals.	O. Simpson

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHOR
n Analysis of Impurity Distribu-ons and their Relation to Elec-ical Behavior of Conventional ransistor Constructions, Part I	Semiconductor Prod April 1959	This article attempts to relate the electrical performance of transistors to the bulk impurity variations inherent in their construction.	P. Kaufmann G. Freedman
me Effects of Semiconductor rfaces on Device Operation	Semiconductor Prod April 1959	The study of the surface involves the outer layers of the bulk material, any absorbed films of foreign material, and the surrounding ambient.	G. deMars
ne Advantages of Tetrode Ge-metry for Power Transistors; ability and Control of Amplified eakage Current	Semiconductor Prod April 1959	A circuit example is given which illustrates the advantage of the tetrode over the equivalent triode configuration.	H. T. Mooers R. J. Zelinka
ransistor Resistor Logic	Semiconductor Prod April 1959	The procedures for optimizing a design and determining design limitations using a particular transistor are outlined.	Q. W. Simkins
requency Variations of the ybrid-Pi Equivalent Circuit unction Transistors	U. S. Govt Res Rep April 17 1959 Order LC PB 136026	Results of the analysis are presented in the forms of graphs and tables.	E. H. Harrison Jr.
adio Frequency Tuners and I-F mplifiers for Transistors	U. S. Govt Res Rep April 17, 1959 Order OTS PB 151545	Miniaturized equipment that can withstand shock, vibration, and temperature conditions between 0°C and 70°C have been designed and constructed.	E. A. Abbott
unch-Thru Diode (Operation as Narrow Base Diode)	U. S. Govt Res Rep April 17, 1959 Order LC PB 130878	Three techniques which have been used to manufacture punch-three diodes are described.	R. H. Rediker D. E. Sawyer
dustrial Preparedness Study on iffused Junction Silicon High peed Computer Diode	U. S. Govt Res Rep April 17, 1959 Order LC PB 136001	Pilot tooling and equipment produced; pilot plant cost and capacity, as well as pilot product manufacturing cost, are described.	S. H. Barnes P. H. Dernbach Et Al
esign Considerations for the adioisotope Thermoelectric Gen-rator	U. S. Govt Res Rep April 17, 1959 Order LC PB 135315	Five-Section report, each of which is part of a predevelopment feasibility study of the radioisotope thermoelectric generator.	F. B. Brauer, J. L. Briggs Et Al
ndustrial Preparedness Study on ower Transistors	U. S. Govt Res Rep April 17, 1959 Order LC PB 136090	Study begun of low voltage operation with a view to changing designs slightly to improve performance.	P. W. Erickson J. F. Battey
laximum Efficiency Transistor witching Circuits	U. S. Govt Res Rep April 17, 1959 Order LC PB 130890	Circuit configurations presented which utilize symmetry possible through the combined use of *n-p-n* and *p-n-p* transistors.	R. H. Baker
esearch Investigations heading Improvements in the Spectro-nemical Analysis of Semicon-uctor Materies (4 papers)	U. S. Govt Res Rep April 17, 1959 Order LC PB 137189, 190, 191, 192	Procedures for the detection of C, S, Se, CL, Br, I, and F with high voltage discharges using briquets in reduced pressure chambers.	C. E. Harvey
roperties of Sulfide Semicon-uctors	U. S. Govt Res Rep April 17, 1959 Order LC 130886	The galvanomagnetic effects in *n*-type germanium have been investigated theoretically and experimentally at 77°K and 300°K.	M. W. Bulles

SEMICONDUCTOR CIRCUIT DESIGN AWARDS RULES

1. **Articles and nomographs published in Semiconductor products between April 1959 and March 1960 inclusive will be considered eligible for the awards. It is therefore advisable to submit manuscripts as soon as possible.**

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4. **Manuscripts are limited to 3,000 words or less, exclusive of illustrations and diagrams. Manuscripts should be typed double-spaced, and submitted in duplicate. Illustrations and diagrams need not be inked or ruled; however they must be neatly prepared and legible.**

5. **Judges' decision shall be final, and authors agree to accept these decisions as a condition of entry. Semiconductor Products reserves the right to correct typographical errors that may appear inadvertently in the manuscript.**

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PATENT REVIEW*

Of Semiconductor Devices, Fabrication Techniques and Processes and Circuits and Applications

Compiled by SIDNEY MARSHALL

The abstracts appearing in this issue cover the inventions relevant to semiconductors from Sept. 18, 1956 to Dec. 25, 1956. In subsequent issues, patents issued from Dec. 25, 1956 to date will be presented in a similar manner. After bringing these abstracts up to date, PATENT Review will appear periodically, the treatment given to each item being more detailed.

September 18, 1956

2,763,832 Semiconductor Circuit Controlling Device—W. Shockley. Assignee: Bell Telephone Laboratories. A device having a semiconductive body with an *n-p-n* construction, and means capable of two states for selectively biasing the intermediate zone in one state positive with respect to both outer zones, and in the other state negative with respect to both said outer zones, said means providing a control of the impedance presented by the body between two terminals connected to said outer zones.

September 25, 1956

2,764,642 Semiconductor Signal Translating Devices—W. Shockley. Assignee: Bell Telephone Laboratories. A semiconductor body having a pair of juxtaposed closely adjacent zones of one conductivity type, the bulk of said body being of the opposite conductivity type, and means for biasing the source and drain connections such that a space charge region bridges the space between said zones.

2,764,674 Transistor Receiver Oscillator Injection Using Capacitance Between Stators of Gang Capacitor—L. E. Barton. Assignee: Bell Telephone Laboratories. A radio frequency and oscillator tuning circuit to provide constant injection of the local oscillator signal to the signal mixer of signal receiving systems of the type employing transistors as active signal amplifying and translating elements.

2,764,678 Pulse Stretcher—J. F. Craib. Assignee: Airborne Instrument Laboratories. An apparatus for elongating electrical impulses comprising a network having a plurality of delay sections, a plurality of nonlinear elements, and means for applying said impulses to said nonlinear elements and means to derive an elongated output signal from the resulting final delay section.

2,764,687 Transistor Automatic Frequency Control—J. M. Buchanan, C. A. Leedy. Assignee: Hoffman Electronics Corporation. An automatic frequency control system employing junction type transistors and including an oscillator, a discriminator coupled to said oscillator, a reactance control circuit coupled to said discriminator and also to said oscillator to complete the automatic frequency control circuit loop.

2,764,688 Electric Trigger Circuits—H. Grayson, A. E. Brewster, T. H. Walker. Assignee: International Standard Electric Corporation. An electric two-condition trigger circuit comprising an amplifying device, means for triggering said device from one condition to the other, means for generating an alternating current and utilizing said current for holding the device in one of said conditions.

October 2, 1956

2,765,245 Method of Making P-N Junction Semiconductor Units—A. C. English, J. B. Seabrook. Assignee: General Electric Company. A method which comprises preparing a germanium or silicon melt with an electrically significant impurity element and depositing said melt while in a liquid state and at a temperature less than 85% of the absolute temperature melting point of semiconductor in said melt upon the surface of a solid semiconductor body having a predominance of carriers whose polarity is opposite to that induced by said impurity element.

October 9, 1956

2,765,986 Photo Transistor Control System—J. P. Pompetti, M. B. Tatonetti. Assignee: Cybertronic Corporation of America. A control system that introduces feedback in the form of an anticipating condition, that provides self-induced temperature compensation, and that obtains power gain in a transistor circuit by means of an optical feedback circuit.

2,766,410 Transistor Devices—B. N. Slade. Assignee: Radio Corporation of America. A point-contact transistor made from a material which provides a device having a high current gain cutoff frequency.

2,766,428 Capacitance Measuring Circuit—F. W. Sippach Jr. Assignee: Weston Electrical Instrument Corporation. Apparatus directly responsive to changes in the capacitance of a test member.

2,767,330 Transistor Control Circuit—J. F. Marshall. Assignee: Minneapolis-Honeywell Regulator Company. Electronic switching means comprising means for biasing a first transistor to a conductive state, means for maintaining a second transistor in a state of nonconduction, and signal producing means connected between the collector and base of said second transistor capable of rendering said second transistor conductive.

2,767,358 Semiconductor Signal Translating Devices—J. M. Early. Assignee: Bell Telephone Laboratories. A device comprising a body of semiconductive material having therein a zone of intrinsic conductivity and a second zone of extrinsic conductivity and of one conductivity type contiguous with said first zone, said device having a low collector-to-base capacity.

2,767,364 Motor Control System—W. B. Griggi. Assignee: Westinghouse Electric Corporation. In combination: an a-c source, a load, a full-wave rectifier, junction transistor means connected to the rectifier output terminals, and pulse generating means adapted to drive said transistor between collector current cut-off and saturation.

2,767,365 Motor Control System—W. B. Guggi. Assignee: Westinghouse Electric Corporation. In combination: An a-c source, a first and second transformer, junction transistor means and provisions for biasing said means between collector current cutoff and saturation in alternation, and load means coupled to the secondary winding of said second transformer.

October 23, 1956

2,768,294 Circuit for Generating Sawtooth Oscillations—A. J. Van Overbeek. Assignee: Hartford National Bank and Trust Company. In a synchronized sawtooth generator means coupled to a transistor for producing sustained oscillations comprising a capacitor, a series circuit arrangement, and means for deriving sawtooth oscillations from said generator.

2,768,296 Semiconductor Phase Controlled Oscillator Circuits—G. B. Herzog. Assignee: Radio Corporation of America. A stable oscillator circuit which may effectively be locked in from information received in the form of a burst of information and which effectively remains locked in until the receipt of the next burst of information.

November 6, 1956

2,769,870 Transistor Amplifier Circuit—J. M. Cluwen. Assignee: Hartford National Bank and Trust Company. A device for adjusting the input impedance of a transistor amplifier to a desired value.

2,769,906 Junction Transistor Oscillator Circuits—M. C. Kidd, W. Hasenberg. Assignee: Radio Corporation of America. In

*Source: Official Gazette of the U. S. Patent Office and Specifications and Drawings of Patents Issued by the U. S. Patent Office.

n oscillator circuit utilizing a semiconucting junction-type device, biasing neans for providing a negative resistance haracteristic over a portion of the operatng range of the oscillator circuit, and a requency determining circuit operative o control the frequency of oscillation of aid oscillator circuit.

,769,907 Semiconductor Relaxation Oscillator Circuits—R.D. Lohman. Assignee: adio Corporation of America. In a relaxtion oscillator circuit; two three-terminal transistors, means including a storage lement coupling the first base electrode ith the second collector electrode, and neans for applying energizing potentials o said transistors to bias them into a curent conducting state.

,769,908 Negative Impedance Transistor ircuits—F. R. Stansel. Assignee: Bell elephone Laboratories. In a transistor ircuit, means for producing a negative nput impedance in the signal input path etween said collector electrode and one f the other electrodes.

,769,926 Non-Linear Resistance Device—. A. Lesk. Assignee: General Electric ompany. A device consisting of a semionductive bar having first and second hmic contacts at opposite ends thereof, nd a region of opposite conductivity type etween said contacts forming a *p-n* unction with said bar.

November 13, 1956

,770,728 Semiconductor Frequency Multilier Circuit—G. B. Herog. Assignee: adio Corporation of America. In a freuency multiplier circuit, a pair of semionductor devices of opposite conductivity ypes and signal input means providing source of input signals of a predeermined frequency for rendering said levices alternately conductive to provide corresponding push-pull output signal f a frequency equal to twice said predetermined frequency.

,770,731 Transistor Oscillator—C. C. Bapp, . W. Bradmiller. Assignee: Avco Manuacturing Corporation. A point-contact ransistor oscillator circuit consisting of: n inductance connected between the ase electrode and a point of reference otential, a piezoelectric crystal conected between the emmiter and said eference point, and a tank output circuit onnected between the collector and said eference point.

,770,732 Transistor Multivibrator Circuit —C. F. Chong. Assignee: Radio Corporaion of America. A circuit comprising a irst and a second semiconductor device f opposite conductivity type, means incluing an electrical storage element conecting the first base electrode with the econd collector, circuit means for receivng trigger pulses for rendering said deices non-conductive and to charge said torage element, means for providing apid discharge of said storage element hrough said semiconductor devices.

2,770,734 Transistor Relay Devices—R. J. Reek. Assignee: Teletype Corporation. In a relay device; a transistor, a control circuit with an inductance having a variable impedance, and means for varying the impedance characteristic of said inductance so as to cause said transistor to oscillate.

2,770,740 Electronic Counting Devices And Circuits Employing Semiconductors—A. H. Reeves, R. B. Cooke. Assignee: International Standard Electric Corporation. An electric pulse counting device having a plurality of rectifying electrodes contacting a surface of a semiconductive body, said contacts being formed to have a negative resistance region, said electrodes having a spacing such that for any adjacent pair of electrodes a charge current passing in the forward direction through one contact produces a change in current in the other contact.

2,770,761 Semiconductor Translators Containing Enclosed Active Junctions—W. G. Pfann. Assignee: Bell Telephone Laboratories. A device comprising a semiconductive body having therein a zone of one conductivity type in contact with a zone of the opposite type, the junction between said zones being enclosed within said body, and means for making contact with one of said zones and another portion of said body.

2,770,762 Crystal Triodes—C. de Boismaison-White, K. A. Matthews. Assignee: International Standard Electric Corporation. An amplifying device including a plurality of point-contact electrodes engaging a semiconductive body, a pair of said electrodes making contact with said body at points close to each other, said pair being emitter and collector with respect to each other, and a third pair of said electrodes contacting said body and spaced at a distance from said pair of electrodes.

2,770,763 Electric Crystal Rectifiers—K. A. Matthews. Assignee: International Standard Electric Corporation. A rectifier consisting of a semiconductive body of one conductivity type having a surface layer of the opposite conductivity type, a low resistance contact electrode, a thin film of the first conductivity type over another part of said layer, and a second electrode making rectifying contact with said thin film.

November 20, 1956

2,771,382 Method of Fabricating Semiconductors for Signal Translating Devices—C. S. Fuller. Assignee: Bell Telephone Laboratories. The method of producing a germanium body having *p-n* junction therein, which comprises applying a silver layer to a portion of an *n*-type body, heating the body for a time to control to a desired depth the conversion to P conductivity type of the surface portion free of silver, and then quenching the body.

2,771,584 Frequency Controlled Transistor Oscillators—D. E. Thomas. Assignee: Bell Telephone Laboratories. In combination, a transistor, means for producing self oscillations thereof, means for providing said transistor with an input signal controlled varying α cut-off frequency whereby the oscillation frequency is varied under the control of the input signal.

November 27, 1956

2,772,359 Synchronized Oscillator—V. J. Modiano. Assignee: Sperry Rand Corporation. A circuit comprising: a tank circuit and means for driving said circuit at its resonant frequency. a transistor, means for increasing the transistor base-current or a half cycle interval of the tank circuit, said increase occurring in response to a synchronizing pulse above the saturation level of the transistor.

2,772,360 Negative Resistance Device—W. Shockley. Assignee: Bell Telephone Laboratories. An oscillator comprising a semiconductive diode having contiguous zones of different predominances of charge carriers, and biasing means for establishing in an intermediate zone an electric field which puts said zone in the range of negative differential mobility for charge carriers traveling through said zone.

2,772,370 Binary Trigger And Counter Circuits Employing Magnetic Memory Devices—G. D. Bruce, J. C. Logue, Assignee: International Business Machines Corporation. A transistorized binary trigger and multiple stage counter circuit employing a magnetic memory device to retain the impression of the last received signal and producing a pulse type output rather than a steady output signal.

2,772,371 Power Supply—B.E. Denton. Assignee: Radio Corporation of America. A transformerless full-wave, doubler-type, power supply providing an operating voltage to a series connected heater string in a manner whereby the peak voltage of the energizing alternating current applied to said power supply is the greatest possible voltage applied across the series-connected heater string.

2,772,410 Transistor Indicator Circuit—J. C. Logue, R. A. Henle. Assignee: International Business Machines Corporation. Visual signal apparatus comprising a glow discharge lamp, a source of unidirectional electrical energy having a potential greater than the lamp's ignition potential, and transistor means for controlling the potential across the lamp.

December 4, 1956

2,773,132 Magnetic Amplifier—R. L. Bright. Assignee: Westinghouse Electric Corporation. A self-saturating magnetic amplifier for amplifying extremely low power level control signals, including self-saturation means comprising a transistor connected to synchronously rectify an *a-c* supply voltage of small amplitude.

2,773,134 Magnetic Amplifiers—W. J. Dunnet. Assignee: Westinghouse Electric Corporation. In a magnetic amplifier the combination comprising a magnetic core member, a rectifier and means for connecting said rectifier with the winding of said core and a load, main and auxiliary voltage sources, means for preventing exciting current from flowing through the load while the auxiliary supply voltage is effecting complete magnetic saturation of the core member.

2,773,200 Direct Current Transformation Device—W. B. Guggi. Assignee: Westinghouse Electric Corporation. Apparatus for transforming the output of a direct voltage source having a given terminal voltage to a second voltage.

2,773,224 Transistor Point-Contact Arrangement—K. Lehovec. Assignee: Sprague Electric Company. A transistor, means defining two closely spaced apertures through the semiconductive body thereof, wire probe means passing through said apertures, point-contact means formed on the tips of said probe means, said point-contact means forming rectifying contacts with said body about 1 to 5 mils apart.

2,773,225 Semiconductor Device—R. L. Jones. Assignee: Columbia Broadcasting System Inc. A transistor comprising a semiconducting body, a base connection thereto, a pair of leads having pointed

[*Continued on page 78*]

CHARACTERISTICS CHARTS OF NEW DIODES and RECTIFIERS

ANNOUNCED BETWEEN JUNE 1, 1959 and JULY 31, 1959 ONLY.

MANUFACTURERS

AEG—	Allgemeine Elekticitats-Gesellschaft
AEI—	Associated Electrical Industries, Ltd.
AMP—	Amperex Electronic Corp.
AUD—	Audio Devices, Inc.
BEN—	Bendix Aviation Corp.
BER—	Berkshire Labs
BOG—	Bogue Electric Mfg. Co.
BOM—	Bomac Labs
BRA—	Bradley Labs
CBS—	CBS Electronics
CDC—	Continental Device Corp.
COL—	Columbus Electronics Corp.
CTP—	Clevite Transistor Products, Inc.
CSF—	Compagnie Generale de T.S.F.
EEVB—	English Electric Valve Co., Ltd.
ERI—	Erie Resistor Corp.
FAN—	Fansteel Metallurgical Corp.
FERB—	Ferranti Ltd.
GAH—	Gahagan, Inc.
GECB—	General Electric Co., Ltd.
GE—	General Electric Company, Semiconductor Div.
GIC—	General Instrument Corp.
GTC—	General Transistor Corp.
HSD—	Hoffman Semiconductor Division
HUG—	Hughes Products Division
IFHS—	Institutet for Halvedarforskning
INRC—	International Rectifier Corp.
IRC—	International Resistance Co.
ITT—	International Tel. & Tel. Corp.
KEM—	Kemtron Electron Products, Inc.
LCTF—	Laboratoire Central de Telecommunications
MAL—	P. R. Mallory & Co., Inc.
MIC—	Microwave Associates, Inc.
MOT—	Motorola, Inc.
MUL—	Mullard, Ltd.
NAE—	North American Electronics
NPC—	Nucleonic Products Co., Inc.
OHM—	Ohmite Manufacturing Co.
PHI—	Philco Corp. Lansdale Tube Company
PSI—	Pacific Semiconductors, Inc.
QSC—	Qutronic Semiconductor Corp.
RAY—	Raytheon Company
RCA—	Radio Corporation of America, Semiconductor Div
RHE—	Rheem Semiconductor Corp.
SAR—	Sarkes Tarzian, Inc., Rectifier Division
SCN—	Semicon, Inc.
SEM—	Semi-Elements Inc.
SIE—	Siemens & Halske Aktiengesellschaft
SIL—	Silicon Transistor Corp.
SSD—	Sperry Semiconductor Division
SSP—	Solid State Products, Inc.
STC—	Shockley Transistor Corp.
STCB—	Standard Telephone & Cables, Ltd.
SYL—	Sylvania Electric Products, Inc.
SYN—	Syntron Co.
TEX—	Texas Research Assoc.
TFKG—	Telefunken, Ltd.
THE—	Thermosen, Inc.
TI—	Texas Instruments, Inc.
TKD—	Tekade, Nurnberg, Germany
TOK—	Tokyo Tsushin Kogyo, Ltd.
TRA—	Transitron Electronic Corp.
TUN—	Tung-Sol Electric, Inc.
TSC—	Trans-Sil Corp.
USD—	United States Dynamics Corp.
USS—	U. S. Semiconductor Products, Inc.
VIC—	Vickers Inc.
WEC—	Western Electric Co.
WEST—	Westinghouse Electric Corp.

The following manufacturers have announced that they have begun supplying the indicated previously registered diodes and rectifiers.

Amperex: 1N456 thru 1N459, 1N461 thru 1N464
Clevite: 1N645, 1N647, 1N649, 1N677, 1N685, 1N687
Nucleonic Products: TP55, TP60
Microwave Assoc.: 1N358, 1N358R, 1N358A, 1N358AR, 1N369, 1N369R, 1N1610, 1N1610R, 1N2127
Motorola: 1N253 thru 1N256, 1N536 thru 1N540, 1N547, 1N1095, 1N1096, 1N1115 thru 1N1120, 1N1351 thru 1N1375, 1N1602 thru 1N1609, 1N1809 thru 1N1836, 1N2043 thru 1N2049
North American Electronics: 1N429, 1N471 thru 1N475
Pacific Semiconductors: 1N645 thru 1N649
Rheem - 1N456 thru 1N459, 1N456A thru 1N459A, 1N461 thru 1N464, 1N461A thru 1N464A, 1N482 thru 1N488, 1N482A thru 1N488A, 1N482B thru 1N485B, 1N625 thru 1N629, 1N643, 1N643A, 1N659 thru 1N663, 1N662A, 1N663A, 1N690 thru 1N693, 1N778 thru 1N804, 1N806 thru 1N809, 1N837 thru 1N845, 1N837A

TYPE NO.	USE (See Code Below)	MAT	PIV (volts)	MAX. CONT. WORK. VOLT. (volts)	Min. Forward Current @ 25°C I_f @ E_f (mA)	(volts)	MAX. D.C. OUTPUT CURRENT[4] @ T (°C) (amps)		MAX. FULL LOAD VOLT. DROP[4] (volts)	Max. Rev. Current I_b @ E_b @ T (uA)	(volts)	(°C)	MFR. (See code at start of charts)
1N456	1	Si	30	25	40	1.0	.09	25		.025	25	25	AMP
1N457	1	Si	70	60	20	1.0	.075	25		.025	60	25	AMP
1N458	1	Si	150	125	7.0	1.0	.055	25		.025	125	25	AMP
1N459	1	Si	200	175	3.0	1.0	.04	25		.025	175	25	AMP
1N461	1	Si	30	25	15	1.0	.06	25		.50	25	25	AMP
1N462	1	Si	70	60	5.0	1.0	.05	25		.50	60	25	AMP
1N463	1	Si	200	175	1.0	1.0	.03	25		.50	175	25	AMP
1N464	1	Si	150	125	3.0	1.0	.04	25		.50	125	25	AMP
1N2512	1	Si	100				4.0	25		250	100	150	RAY
1N2513	1	Si	200				4.0	25		250	200	150	RAY
1N2514	1	Si	300				4.0	25		300	300	150	RAY
1N2515	1	Si	400				4.0	25		300	400	150	RAY
1N2516	1	Si	500				4.0	25		350	500	150	RAY
1N2517	1	Si	600				4.0	25		400	600	150	RAY
1N2518	1	Si	100				4.0	25		250	100	150	RAY
1N2519	1	Si	200				4.0	25		250	200	150	RAY
1N2520	1	Si	300				4.0	25		300	300	150	RAY
1N2521	1	Si	400				4.0	25		300	400	150	RAY
1N2522	1	Si	500				4.0	25		350	500	150	RAY
1N2523	1	Si	600				4.0	25		400	600	150	RAY
3B30S	5	Si	30		2A	2.5	1.0	100C		10	30	25	SSP
3B60S	5	Si	60		2A	2.5	1.0	100C		10	60	25	SSP
3B100S	5	Si	100		2A	2.5	1.0	100C		10	100	25	SSP
3B150S	5	Si	150		2A	2.5	1.0	100C		10	150	25	SSP
3B200S	5	Si	200		2A	2.5	1.0	100C		10	200	25	SSP

NOTATIONS

Under Use

1. General Purpose
2. Power Rectifier
3. Magnetic Amplifier
Ø Insulated Base
5. Controlled Rectifier
6. Dual Rectifier
△ Direct Tube Replacement

Other

4. For half wave resistive load average over 1 cycle

Under Reverse Current

☑ Dynamic

Under Mfr.

6. Available in stack form from that manufacturer

Following any temperature reading these symbols apply

A — Ambient
C — Case
J — Junction
S — Storage
△ — Inlet Temperature of Coolant

Type No.

† — Revised Data

Manufacturers should be contacted for value and test condition for surge current and maximum peak recurrent current

Under E_f
☑ - at 125°C

TYPE NO.	USE (See Code Below)	MAT	PIV (volts)	MAX. CONT. WORK. VOLT. (volts)	Min. Forward Current @ 25°C I_f @ E_f (mA)	(volts)	MAX. D.C. OUTPUT CURRENT[4] @ T (°C) (amps)	MAX. FULL LOAD VOLT. DROP[4] (volts)	Max. Rev. Current I_b @ E_c @ T (uA)	(volts)	(°C)	MFR. (See code at start of charts)
10E5	2	Si	100				.75	65A	250	100	100A	AUD
20E5	2	Si	200				.75	65A	250	200	100A	AUD
30E5	2	Si	300				.75	65A	250	300	100A	AUD
40E5	2	Si	400				.75	65A	250	400	100A	AUD
50E5	2	Si	500				.75	65A	250	500	100A	AUD
60H	2	Si	600				.75	55	100	600	55	SAR
2005	2	Si	50	35	10A	1.2	15	25	1.0 10ma	50	150C	SYN
2010	2	Si	100	70	10A	1.2	15	25	1.0 10ma	100	150C	SYN
2015	2	Si	150	105	10A	1.2	15	25	1.0 10ma	150	150C	SYN
2020	2	Si	200	140	10A	1.2	15	25	1.0 10ma	200	150C	SYN
2025	2	Si	250	175	10A	1.2	15	25	1.0 10ma	250	150C	SYN
2030	2	Si	300	210	10A	1.2	15	25	1.0 10ma	300	150C	SYN
2035	2	Si	350	245	10A	1.2	15	25	1.0 10ma	350	150C	SYN
2040	2	Si	400	280	10A	1.2	15	25	1.0 10ma	400	150C	SYN
E200	2	Si	360				.20	55A	500	360	80A	AUD
E450C50Si	1	Si		450			.05	50A	1.0 4.0	1500	120J	AEG
E1500C50Si	1	Si		1500			.05	50A	1.5 4.0	4500	120J	AEG
Ge015F	1	Ge		160			.15	35A	.20 600	250	65J	AEG
Ge015C	1	Ge		55			.15	35A	.20 600	100	65J	AEG
Ge015E	1	Ge		110			.15	35A	.20 600	175	65J	AEG
Ge015G	1	Ge		220			.15	35A	.20 500	350	65J	AEG
Ge025C	1	Ge		55			.25	35A	.20 600	100	65J	AEG
Ge025E	1	Ge		110			.25	35A	.20 600	175	65J	AEG
Ge025F	1	Ge		160			.25	35A	.20 600	250	65J	AEG
Ge025G	1	Ge		220			.25	35A	.20 600	350	65J	AEG
Ge100B	2	Ge		35			75	35A	.25 60ma	55	65J	AEG
Ge100D	2	Ge		70			75	35A	.25 70ma	115	65J	AEG
Ge100E	2	Ge		110			75	35A	.25 75ma	175	65J	AEG
OY100	1	Si		400			.40	50A	.60 400	700	120J	AEG
PS2207	1	Si	70		100	1.0			5000	10	150	PSI
PS2208	1	Si	70		100	1.0			5000	10	150	PSI
PS2209	1	Si	70		100	1.0			5000	10	150	PSI
PS2245	1	Si	225				.50		30	225	100	PSI
PS2246	1	Si	300				.50		30	300	100	PSI
PS2247	1	Si	400				.50		40	400	100	PSI
PS2248	1	Si	500				.50		40	500	100	PSI
PS2249	1	Si	600				.50		50	600	100	PSI
S11E	1	Si		110			.40	50A	.60 400	175	120J	AEG
S11F	1	Si		160			.40	50A	.60 400	250	120J	AEG
S11G	1	Si		220			.40	50A	.60 400	350	120J	AEG
S11H	1	Si		300			.40	50A	.60 400	475	120J	AEG
S11K	1	Si		380			.40	50A	.60 400	600	120J	AEG
S13E	2	Si		110			3.0	35A	.60 1500	175	120J	AEG
S13F	2	Si		160			3.0	35A	.60 1500	250	120J	AEG
S13G	2	Si		220			3.0	35A	.60 1500	350	120J	AEG
S13H	2	Si		300			3.0	35A	.60 1500	475	120J	AEG
S13K	2	Si		380			3.0	35A	.60 1500	600	120J	AEG
S18E	2	Si		110			8.0	35A	.60 6000	175	120J	AEG
S18F	2	Si		160			8.0	35A	.60 4000	250	120J	AEG
S18G	2	Si		220			8.0	35A	.60 2000	350	120J	AEG
S18H	2	Si		300			8.0	35A	.60 2000	475	120J	AEG
S18K	2	Si		380			8.0	35A	.60 2000	600	120J	AEG
S120E	2	Si		110			20	35A	.60 14ma	175	120J	AEG
S120F	2	Si		160			20	35A	.60 11ma	250	120J	AEG
S120G	2	Si		220			20	35A	.60 9000	350	120J	AEG
S120H	2	Si		300			20	35A	.60 9000	475	120J	AEG
S120K	2	Si		380			20	35A	.60 9000	600	120J	AEG
S140E	2	Si		110			60	35A	.65 10ma	175	120J	AEG
S140F	2	Si		160			60	35A	.65 10ma	250	120J	AEG
S140G	2	Si		220			60	35A	.65 15ma	350	120J	AEG
S140H	2	Si		300			60	35A	.65 15ma	475	120J	AEG
S140K	2	Si		380			60	35A	.65 20ma	600	120J	AEG
ST1	6Δ	Si	1500				.085	75	2.25			INRC
ST2	6Δ	Si	1600				.60	75	3.0			INRC
ST2A	6Δ	Si	2800				.20	75	6.0			INRC
ST3	6Δ	Si	1600				.60	75	3.0			INRC
ST4	6Δ	Si	1600				.60	75	3.0			INRC
ST5	6Δ	Si	1500				.085	75	2.25			INRC
ST6	6Δ	Si	1500				.085	75	2.25			INRC
ST7	2Δ	Si	6400				.25	75	12			INRC

CHARACTERISTICS CHART of SILICON ZENER or AVALANCHE DIODES

TYPE NO.	Zener or Avalanche Voltage Range			Dynamic Impedance		MAX. DISS.	TEMP. CO-EFFICIENT	MFR. { See code at start of chart }
	MIN. E_{b1} (volts)	MAX. E_{b2} (volts)	@ I_z (ma)	Z @ I_z (ohms)	(ma)	(mw)	%/°C	
1N2043A	6.18	6.83	1000	.80	1000	10W	.038	MOT, TRA
1N2043B	6.65	7.35	1000	.80	1000	10W	.043	MOT, TRA
1N2043C	7.13	7.88	1000	.80	1000	10W	.047	MOT, TRA
1N2044A	7.60	8.40	1000	.80	1000	10W	.05	MOT, TRA
1N2044B	8.08	8.93	1000	.80	1000	10W	.054	MOT, TRA
1N2044C	8.55	9.45	1000	.80	1000	10W	.057	MOT, TRA
1N2044D	9.04	9.98	1000	.80	1000	10W	.058	MOT, TRA
1N2045A	9.50	10.50	500	1.5	500	10W	.06	MOT, TRA
1N2045B	10.45	11.55	500	1.5	500	10W	.06	MOT, TRA
1N2046A	11.40	12.60	500	2.0	500	10W	.066	MOT, TRA
1N2046B	12.35	13.65	500	2.0	500	10W	.069	MOT, TRA
1N2046C	13.30	14.70	500	2.0	500	10W	.072	MOT, TRA
1N2047A	14.25	15.75	500	3.0	500	10W	.075	MOT, TRA
1N2047B	15.20	16.80	500	3.0	500	10W	.076	MOT, TRA
1N2047C	16.15	17.85	500	3.0	500	10W	.077	MOT, TRA
1N2048A	17.10	18.90	500	3.0	500	10W	.078	MOT, TRA
1N2048B	18.05	19.95	500	3.0	500	10W	.079	MOT, TRA
1N2048C	19.0	21.0	500	3.0	500	10W	.081	MOT, TRA
1N2049A	20.9	23.1	150	8.0	150	10W	.084	MOT, TRA
1N2049B	22.8	25.2	150	8.0	150	10W	.086	MOT, TRA
1N2049C	24.7	27.3	150	8.0	150	10W	.088	MOT, TRA
1N2620	8.9	9.7	10	15max	10	750	.01	MOT
1N2620A	8.9	9.7	10	15max	10	750	.01	MOT
1N2620B	8.9	9.7	10	15max	10	750	.01	MOT
1N2621	8.9	9.7	10	15max	10	750	.005	MOT
1N2161A	8.9	9.7	10	15max	10	750	.005	MOT
1N2621B	8.9	9.7	10	15max	10	750	.005	MOT
1N2622	8.9	9.7	10	15max	10	750	.002	MOT
1N2622A	8.9	9.7	10	15max	10	750	.002	MOT
1N2622B	8.9	9.7	10	15max	10	750	.002	MOT
1N2623	8.9	9.7	10	15max	10	750	.001	MOT
1N2623A	8.9	9.7	10	15max	10	750	.001	MOT
1N2623B	8.9	9.7	10	15max	10	750	.001	MOT
1N2624	8.9	9.7	10	15max	10	750	.0005	MOT
1N2624A	8.9	9.7	10	15max	10	750	.0005	MOT
1N2624B	8.9	9.7	10	15max	10	750	.0005	MOT
1N2765	6.36	7.14	7.5	20	7.5			PSI
1N2766	12.92	14.28	7.5	40	7.5			PSI
1N2767	19.38	21.42	7.5	60	7.5			PSI
1N2768	25.84	28.56	7.5	80	7.5			PSI
1N2769	32.3	35.7	7.5	100	7.5			PSI
1N2770	38.76	42.87	7.5	120	7.5			PSI
3/4M6.8Z	5.4	8.2	37	3.5	37	750	.04	MOT
3/4M7.5Z	6.0	9.0	34	4.0	34	750	.045	MOT
3/4M8.2Z	6.6	9.8	31	4.5	31	750	.048	MOT
3/4M9.1Z	7.3	10.9	28	5.0	28	750	.051	MOT
3/4M10Z	8.0	12.0	25	7	25	750	.055	MOT
3/4M11Z	8.8	13.2	23	8	23	750	.06	MOT
3/4M12Z	9.6	14.4	21	9	21	750	.065	MOT
3/4M13Z	10.4	15.6	19	10	19	750	.065	MOT
3/4M14Z	11.2	16.8	18	12	18	750	.07	MOT
3/4M15Z	12.0	18.0	17	14	17	750	.07	MOT
3/4M16Z	12.8	19.2	15.5	16	15.5	750	.07	MOT
3/4M17Z	13.6	20.6	14.5	18	14.5	750	.075	MOT
3/4M18Z	14.4	21.6	14	20	14	750	.075	MOT
3/4M19Z	15.2	22.8	13	21	13	750	.075	MOT
3/4M20Z	16.0	24.0	12.5	22	12.5	750	.075	MOT
3/4M22Z	17.6	26.4	11.5	23	11.5	750	.08	MOT
3/4M24Z	19.2	28.8	10.5	25	10.5	750	.08	MOT
3/4M25Z	20.0	30.0	10	30	10	750	.08	MOT
3/4M27Z	21.6	32.4	9.5	35	9.5	750	.085	MOT
3/4M30Z	24.0	36.0	8.5	40	8.5	750	.085	MOT
3/4M33Z	26.4	39.6	7.5	45	7.5	750	.085	MOT
3/4M36Z	28.8	43.2	7.0	50	7.0	750	.085	MOT
3/4M39Z	31.2	46.8	6.5	60	6.5	750	.09	MOT
3/4M43Z	34.4	51.6	6.0	70	6.0	750	.09	MOT
3/4M45Z	36.0	54.0	5.5	75	5.5	750	.09	MOT
3/4M47Z	37.6	56.4	5.5	80	5.5	750	.09	MOT
3/4M50Z	40.0	60.0	5.0	90	5.0	750	.09	MOT
3/4M52Z	41.6	62.4	5.0	100	5.0	750	.09	MOT

TYPE NO.	Zener or Avalanche Voltage Range			Dynamic Impedance		MAX. DISS.	TEMP. CO-EFFICIENT	MFR. (See code at start of chart)
	MIN. E_{b1} (volts)	MAX. E_{b2} (volts)	@ I_z (ma)	Z @ I_z (ohms)	(ma)	(mw)	%/°C	
3/4M56Z	44.8	67.2	4.5	110	4.5	750	.09	MOT
3/4M62Z	49.6	74.4	4.0	125	4.0	750	.09	MOT
3/4M68Z	54.4	81.6	3.7	150	3.7	750	.09	MOT
3/4M75Z	60.0	90.0	3.3	175	3.3	750	.09	MOT
3/4M82Z	65.6	98.4	3.0	200	3.0	750	.09	MOT
3/4M91Z	72.8	109	2.8	250	2.8	750	.09	MOT
3/4M100Z	80.0	120	2.5	350	2.5	750	.09	MOT
3/4M105Z	84.0	126	2.5	400	2.5	750	.095	MOT
3/4M110Z	88.0	132	2.3	450	2.3	750	.095	MOT
3/4M120Z	96.0	144	2.0	550	2.0	750	.095	MOT
3/4M130Z	104	156	1.9	700	1.9	750	.095	MOT
3/4M140Z	112	168	1.8	900	1.8	750	.095	MOT
3/4M150Z	120	180	1.7	1000	1.7	750	.095	MOT
3/4M175Z	140	210	1.4	1200	1.4	750	.095	MOT
3/4M200Z	160	240	1.2	1500	1.2	750	.10	MOT
KS30A	3.13	3.47	5.0	110	5.0	150	.06	FERB
KS30B	2.97	3.63	5.0	110	5.0	150	.06	FERB
KS31A	3.42	3.78	5.0	110	5.0	150	.05	FERB
KS32A	3.7	4.1	5.0	90	5.0	150	.04	FERB
KS32B	3.51	4.29	5.0	90	5.0	150	.04	FERB
KS33A	4.08	4.52	5.0	80	5.0	150	.03	FERB
KS34A	4.46	4.94	5.0	75	5.0	150	.02	FERB
KS34B	4.23	5.17	5.0	75	5.0	150	.02	FERB
KS35A	4.84	5.36	5.0	65	5.0	150	.01	FERB
KS36A	5.32	5.88	5.0	60	5.0	150	.00	FERB
KS36B	5.04	6.16	5.0	60	5.0	150	.00	FERB
KS37A	5.89	6.51	5.0	50	5.0	150	.03	FERB
KS38A	6.46	7.14	5.0	45	5.0	150	.04	FERB
KS38B	6.80	7.48	5.0	45	5.0	150	.04	FERB
KS39A	7.13	7.88	5.0	42	5.0	150	.05	FERB
KS40A	7.79	8.61	5.0	40	5.0	150	.05	FERB
KS40B	8.20	9.02	5.0	40	5.0	150	.05	FERB
KS41A	8.65	9.56	5.0	35	5.0	150	.06	FERB
KS42A	9.5	10.5	5.0	30	5.0	150	.06	FERB
KS42B	9.0	11.0	5.0	30	5.0	150	.06	FERB
KS43A	10.45	11.55	5.0	27	5.0	150	.07	FERB
KS44A	11.4	12.6	5.0	25	5.0	150	.07	FERB
KS44B	10.8	13.2	5.0	25	5.0	150	.07	FERB

CHARACTERISTICS CHART of SWITCHING DIODES

TYPE NO.	MAT	PIV (volts)	MAX. CONT. REV. WORK. VOLT. (volts)	Min. Forward Current @ 25°C I_f @ E_f (mA)	(volts)	Reverse Impedance @ 25°C Z (K ohms)	VOLTAGE RANGE E_{b1} to E_{b2} (volts)	Recovery Characteristics TEST CONDITIONS Fwd. Rev. I_f to E_b (ma)	(volts)	$Z_{rec.}$ @ time (t) (K ohms)	(usec)	MFR. (See code at start of charts)
PD1	Si			5	50			5	40	100	1.0	PSI
PD021	Si			20	50			5	40	100	.30	PSI
PD031	Si			5	100			5	40	100	.30	PSI
PD034	Si			20	100			5	40	100	.30	PSI
PD041	Si			10	200			5	40	200	.30	PSI
PD042	Si			10	200			5	40	200	.30	PSI

CHARACTERISTICS CHART of MISCELLANEOUS DIODE TYPES

TYPE NO.	CLASSIFICATION	DESCRIPTION	MFR.
KF11	4	Grain boundary Photo Duo-Diode	NPC

Notations Under Classification

1. Microwave diodes
2. Mixer or detector diodes
4. Photodiodes
5. Solar Cells
6. Harmonic Generator diodes
7. 4-Layer bistable diodes

MARKET NEWS...

Financial

Sales at Bendix Aviation for the second quarter in 1959 were $181,062,617 while profits were $6,818,788. Last year during the same period sales were $155,278,951 and profits $4,670,740.

For the first six months of this year Columbia Broadcasting System, Inc. has reported sales of $215,089,500 and profits of $13,318,871. This is above last year's figures of $201,433,378 in sales and $12,521,-556 in profits for the same period.

Consolidated Electrodynamics has reported sales of $21,135,000 and profits of $858,844 for the first six months of 1959 as compared with sales of $15,382,000 and profits of $30,292 in the same period during 1958.

Erie Resistor Corp. has reported consolidated sales for the first 24 weeks of 1959, ending June 14, to be $10,579,110 as compared with $9,384,450 for the same period in 1958. The earnings during this period were equivalent to 20¢ per common share as compared with 22¢ last year. Earnings and sales this year were affected by an 85 day strike. Future expansion is planned for their wholly owned subsidiary, Electron Research, Inc. formed last spring, to produce Erie Resistor's semiconductor products.

General Transistor Corp. reports sales for the first six months as running nearly 100% above those for 1958. Net earnings during this period were $350,197 compared with $205,270 for the similar period in 1958. This, after giving effect to the two-for-one stock split in July, 1959, is equal to 40¢ a share on 875,346 shares as against 32¢ a share on 630,000 shares outstanding last year. The company has expanded their production of transistors alone to include a line of diodes. Development on "mesa" diodes has been completed and plans are to have them in the market in the very near future.

Hoffman Electronics Corp. has reported net earnings of $1,111,705 for the first six months of 1959 as compared with $831,747 for the same period in 1958. Sales of $22,-345,189 were reported for this period against $18,573,513 last year. The semiconductor division had sales of approximately $5,000,000 for the first half of this year as compared with $5,751,000 for the entire year of 1958. Hoffman's backlog was almost $75,500,000 as of June 30, compared with $25,200,000 a year earlier.

International Tel. and Tel. Co. has increased their sales and profits during the second quarter of this year over last year. They have reported sales of $174,116,100 and profits of $7,628,622 as against sales of $155,555,447 and profits of $6,320,635 last year.

Motorola Inc. announced second quarter net sales of $65,214,062 an increase of 49% over results in 1958, and net earnings of $3,269,944 or $1.69 per share, four times higher than last year. Second quarter sales were 2.4% higher than the record 1959 first quarter, and earnings were up 25%. For the first six months sales and earnings also established a new record for Motorola. During this period net sales were $128,867,246 and net earnings were $5,886,371, versus $84,544,562 and $1,478,297 respectively for 1958.

Raytheon Co. has reported profits of $5,050,000 on sales of $232,082,000 for the first half of 1959 ending June 28. The per share earnings were $1.49 as compared with $1.29 during the same period in 1958.

Sperry Rand has had sales of $274,694,309 for this year's quarter as against $210,054,-464 for the first quarter in 1958.

Texas Instruments, Inc. has reported the highest earnings for any period on record for both the second quarter and the first half ending June 30. Net earnings were $6,305,000 for the first six months from sales of $94,199,000. Their manufacturing backlog as of June 30 was reported at about $85,650,000 of which $42,800,000 was on direct contracts with the U.S. Gov't.

Tung-Sol Electric Inc. reports net sales for the 26 weeks ended June 27, 1959 totaled $35,048,196, an increase of 25% over the $27,962,992 reported for the 26 weeks ended June 28, 1958. Net earnings for the 1959 period totaled $1,406,610 as against $979,750 for the first half of 1958. Per share earnings for the first half of 1959 equaled $1.40 per share, after preferred dividends, on the 922,088 common shares outstanding at the end of the period. This was an increase of 47% over the per share earnings of 95¢ reported for the first 26 weeks of 1958 on the 894,126 common shares then outstanding.

U.S. Transistor Corp has recently offered 180,000 shares of stock at $2.00 per share for sale to residents of New York State. There are presently 300,000 shares outstanding. The corporation has acquired the marketing facilities and personnel of the now defunct Super Electronic Corp., distributor of electroni equipment here and abroad. Prototyp production of computor type germaniun transistors are expected to be availabl from their new plant in Syosset, L.I. b early Fall. P-N-P silicon transistors wil be manufactured by November.

Prices

Motorola has announced price reduc tions on some of its transistors. The 2N70 mesa amplifier has been reduced fror $32.25 to $14.65. Likewise, the 2N695 ultr highspeed switching mesa has dropped i price from $36.75 to $16.85. Price reduc tions from 1/3 to 1/2 have also been mad on their high current switching powe transistors.

The Semiconductor Division of Ray theon Co. has reduced OEM prices on 1 military-type transistors and on 9 com mercial units. Reductions on militar types range from 21 to 36 percent, averag ing $2.25 per unit; and on commercia types from 11 to 20%, averaging 85¢ pe unit.

Texas Instruments has recently ex hibited a glass-headed general purpos germanium transistor which will sell i the neighborhood of 50¢.

Distribution

Cornell-Dubilier Corporation has re cently negotiated with the Tokyo Shi baura Electric Co., Ltd. of Tokyo, Japan an agreement to be their sales representa tion in the U.S. and Canada for the Jap anese company's semi-conductor product such as transistors, diodes and ther mistors. This first venture into the solic state field is expected to provide valu able experience for the company's future endeavors in the field.

General Transistor Distributing Corpo ration, a subsidiary of General Transisto Corp., Jamaica, N.Y., has signed an agree ment with Columbus Electronic Corp. o Yonkers, N.Y., to set up Columbus Elec tronic Distributors in the United State of Columbus' silicon rectifier line.

Hoffman Electronics Corp. Semicon ductor Division is opening an area sales

engineering office in San Diego, Cal. to provide semiconductor sales engineering service in the San Diego area as well as in Arizona and New Mexico.

The semiconductor division of Hughes Aircraft has opened new district sales offices in Minneapolis and Cincinnati. Before the end of the year, other offices will be opened in Baltimore, Denver, Long Island, N.Y., Orlando, Fla. and San Diego. They have eight other offices already in operation throughout the country.

Military

The Defense Department's newly reorganized Electronic Production Resources Agency (ERPA) has estimated that the military requirements for the next two and one-half years will increase 100%, and for the next six years there will be a tenfold increase. It is estimated that military needs will reach a minimum total of nearly 20 million units by 1961, nearly doubling the 1959 military consumption.

Sales & Shipments

The United States Department of Commerce in its "Midyear Review of the Electronics Industries" expects the semiconductor output during 1959 to increase about 40% over 1958—from an estimated $210 million to over $300 million. Semiconductor output (in dollars) is already double the total electron tube output of only a decade ago. Though the present magnitude of the industry will result in slower future growth rates, the inherent advantages of semiconductor devices have still been only partially exploited. Current developments in microminiaturization, automation, and cost reductions resulting from major break-throughs in semiconductor fabrication techniques will greatly expand semiconductor applications and total electronic markets as well. However, recent improvements in receiving tube technology may slow down the replacement of receiving tubes by semiconductors.

The Bureau of Mines has reported that the production and shipments of selenium in the second quarter of this year has gained over the like period in 1958. Second quarter were 278,453 pounds of contained selenium against 179,149 pounds a year ago.

Contracts Awarded

Byron Jackson Div., Borg-Warner Corp., Santa Ana, Cal. $68,910 for various germanium semiconductor devices IFB 33-604-59-720.

Dynatronics, Inc., Orlando, Fla. $70,771 to develop a transistorized analog-to-digital binary coding telemetering device and dual channel high frequency transmitter, (RFP 82806 & 82807).

Kemtron Electron Products, Inc., Newburyport, Mass. $95,700 for semiconductor devices IFB 33-604-59-578.

Microwave Associates, Inc., Burlington, Mass. $33,810 for silicon semiconductor devices. IFB 33-604-59-745.

Motorola, Inc., Phoenix, Ariz. $366,040 contract #81296 Industrial preparedness measure and reports on transistors.

Sterling Radio Products, Inc., Houston $38,420.80 for three items of silicon crystal diode semiconductors IFB—41.

Sylvania Electric Products Inc., Woburn, Mass. $34,662 for semiconductor device, diode. Contract #84765.

Tence Electronics Inc., Boston. $6,274.12 for 404 semiconductor devices ORD-01-021-60-10011.

Western Electric Co., Inc., N.Y. $39,658 for 11,630 semiconductor devices, diode, contract #84787.

New Companies

Dallons Laboratories, Inc., Los Angeles is entering the semiconductor business for the first time. The firm previously specialized in piezoelectric products, ultrasonic and RF generators, and mercury delay lines. It is starting a production run on silicon rectifiers in the medium power range. The firm also manufactures machinery for the semiconductor industry.

Expansions

Nippon Electric Co., Ltd., of Tokyo, Japan, expects to increase their production of transistors to 1.2 million units a month when their new plant is completed.

Silicon Transistor Corp., Carle Place, N.Y. are manufacturing their first silicon transistors, types 2N1069 and 2N1070. Up until now the company has marketed only silicon diodes.

Tokyo Shibaura Electric Co., Ltd., Kawasaki, Japan, has started producing silicon rectifiers. At present these rectifiers have a capacity of 80 amperes. Plans call for increasing the current capacity to 400 amperes.

United Components, Inc., Newark, N.J. is setting up a pilot line to produce silicon glass diodes. They are also planning to enter the silicon transistor field in the near future.

Western Electric Company is expecting to start grading work this fall for the construction of a new plant near Lee's Summit, Mo. The first unit is expected to be completed in 1962. It will consist of a $12 million plant of 600,000 square feet for the manufacture of telephone sets and such electronic devices as transistors, vacuum tubes and diodes.

Sylvania has arranged to purchase a 25,000-square-foot plant at Manchester, N.H. for the manufacture of transistors. Manufacturing operations are scheduled to begin early in 1960.

Fairchild Semiconductor Corporation simultaneously announced the official opening of its new 68,000 square foot production facility at Mountain View, California and plans for further plant expansion expected to reach 120,000 square feet by 1960.

Narda Ultrasonic Corporation has expanded into a second building in Westbury, L.I. The new building is a 10,000 square foot, one-story structure at 50 Sylvester Street adjacent to the main Narda plant.

Ground was broken for a new Bell Telephone Laboratories building at Holmdel, New Jersey. Initial occupancy will start late in 1961.

Microwave Associates, Burlington, Mass., announced construction of a new wing to be added to the present plant. The building will be utilized by the firm's expanding semiconductor and tube operations. Completion is scheduled for early Spring.

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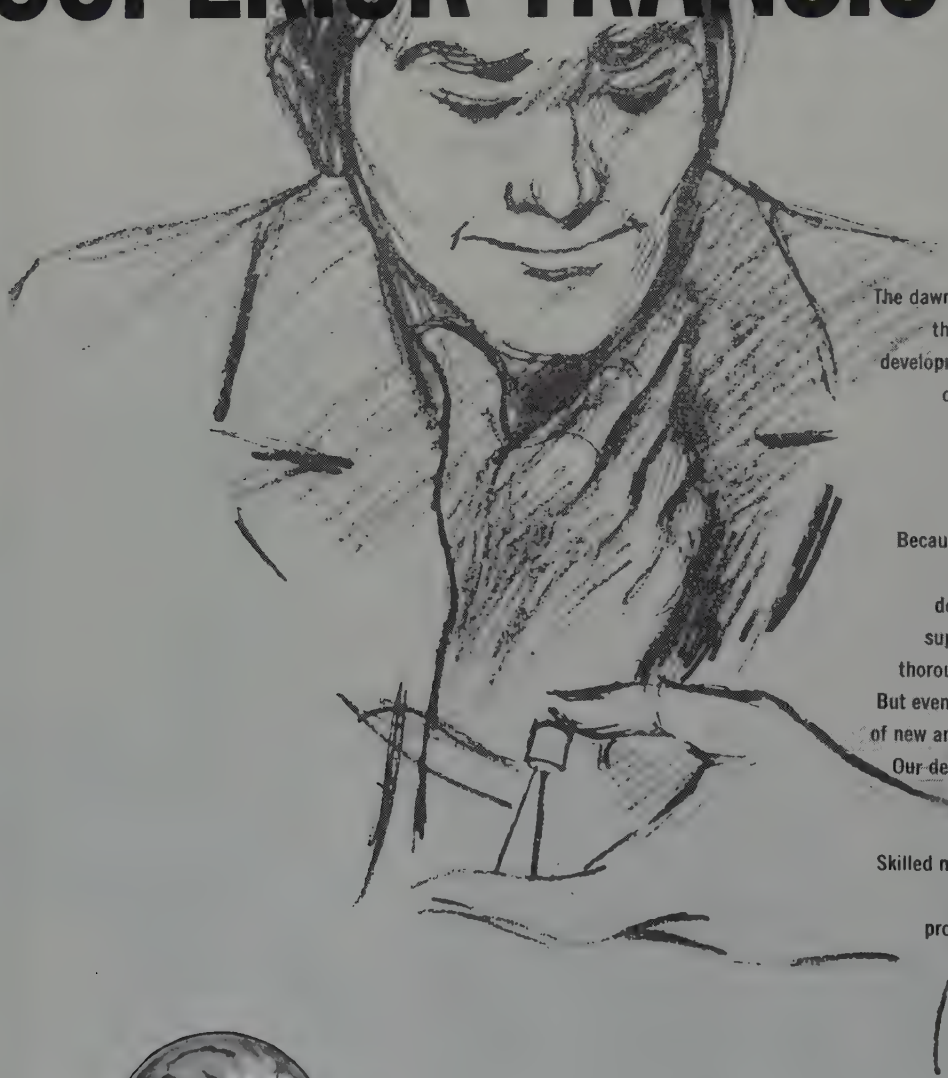
AN IMPORTANT ANNOUNCEMENT INTRODUCING A QUALIFIED SOURCE FOR SUPERIOR TRANSISTORS



The dawn of the space age has brought about the need for absolute perfection in the development, manufacture and performance of electronic equipment. There is only one chance or failure... THERE IS NO SECOND CHANCE.

Because of this crying need for perfection, the U.S. Transistor Corporation has dedicated itself to the manufacture of superior transistors through sound and thorough design and production methods. But even this is not enough in today's myriad of new and amazing electronic developments. Our dedication to a superior product plus a constant inventory and the ability to deliver on schedule tells our story. Skilled minds know-how and a thoroughness that can only be acquired by men of professional engineering ability is once again the story of U.S. Transistor.

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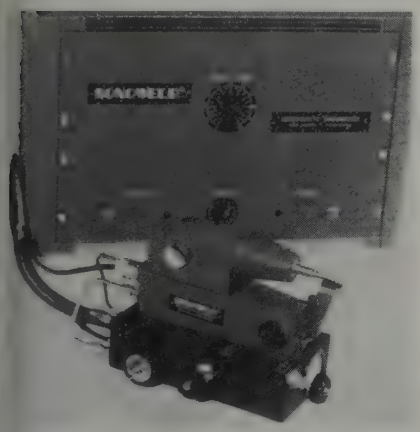
New Products

Small Ultrasonic Welder

A new instrument-type ultrasonic welder designed to make welds in small parts and delicate assemblies has been developed by Aeroprojects. This unit, with a power capacity of 100 watts, is designated Sonoweld Model W-100-TSL-58-6. Many difficult-to-join metal combinations are handled by the Sonoweld unit. Ohmic contacts are made between such semiconductors as silicon or germanium and aluminum or gold wire. Electric match and other fine bridge wire assemblies using high resistance wire in the thickness range of 0.003 to less than 0.001 inch are welded with a high degree of reproducibility. A large number of other dissimilar metal combinations are also joined successfully.

Circle 114 on Reader Service Card



Transistor Series

A new high quality economical alloy junction transistor series was made possible by the perfection of an all-glass header manufacturing process which has been under development by Texas Instruments for more than two and one-half years. Ten types of industrial P-N-P units were announced for general purpose industrial applications. All feature 250 milliwatts dissipation, 200 milliamps collector current and operation to 100°C. Six new P-N-P entertainment types have a maximum junction temperature rating of 85°C.

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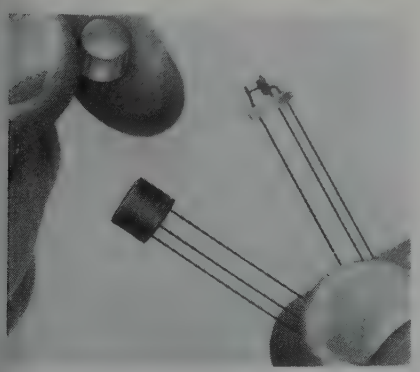

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SECTION HEAD

Application engineer with experience in semiconductor transistor circuit application. Position requires knowledge of applications, sales engineering and a familiarity with various electronic manufacturing industries which manufacture or use semiconductors. Responsibilities will include the direction of fifteen technical people. Master's degree preferred.

These positions were created as a result of the sustained growth of advanced research and development activity at the Semiconductor Division of Hughes Products (Hughes Aircraft Co.). The recently completed ultramodern facilities of the Semiconductor Division are located in Newport Beach, California—just south of Los Angeles. Here you will find choice suburban living in the heart of the Western electronic industry.

If you meet the requirements for the above positions, or if you are a senior engineer or physicist with experience in the field of semiconductors, we invite your inquiry.

Please contact:

Mr. C. L. M. Blocher
Scientific Staff Representative
HUGHES SEMICONDUCTOR DIVISION
500 Superior Avenue
Newport Beach 12, California

HUGHES PRODUCTS

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Silicon Rectifiers

Designed as a direct replacement for 866 mercury vapor rectifier tubes, the Tarzian S-5130 Silicon Rectifier is capable of continuous duty operation of 300 ma dc at 10,400 PIV with a resistive-inductive load. Requires no filament power or warmup period. Shock hazard is minimized by use of an impregnated housing. Capable of operation in temperatures to 100°C, it is ideal for use in applications which demand ruggedness, efficiency and ability to withstand temperature variation.

Circle 180 on Reader Service Card

Transistor For Military

The 2N297A transistor is now in production at the Semiconductor Products plant of Bendix. It can be used in numerous military applications, such as missiles and supersonic aircraft. Has many applications to high current switching, audio amplification, voltage regulators, power supply circuits and power oscillator circuits. Maximum collector voltage rating, 60 volts. Maximum collector current rating, 5 amperes.

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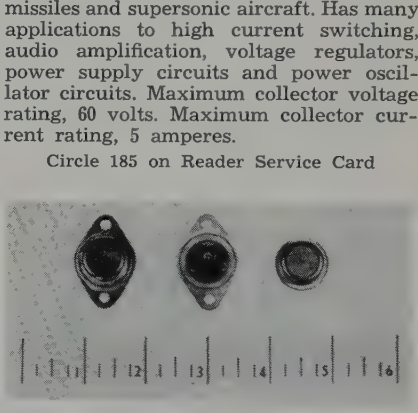

High Power Diodes

U. S. Semcor announces small high power, lightweight diodes which include a 35-watt zener diode. The new line comprises single diffused silicon junction zeners with voltages ranging from 8.2 to 100 volts and rectifiers with PIVs from 50 to 600 volts. Built with matched coefficients of expansion which prohibit separation of internal lead wire and silicon wafer, even under extreme thermal shock. They are not position-sensitive and are highly resistant to vibration. These hermetically sealed diodes have plated copper heat sink and provide excellent thermal conduction.

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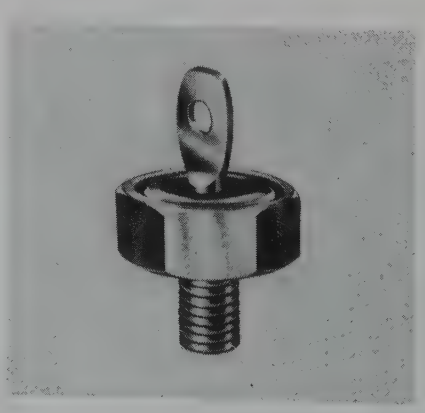

Glass Diode

Silicon glass diodes designed specifically to meet military high reliability programs are available from Silicon Transistor Corp., manufacturers of silicon transistors and diodes. These miniature diodes, which are hermetically sealed, feature fast switching high temperature operation to 200°C. and extremely low leakage at 150° C. Maximum working voltage up to 300 volts and forward conductance to 200 mA @ +1 volt. Typical applications are missiles, missile guidance systems and other airborne equipment, in addition to commercial and industrial computers.

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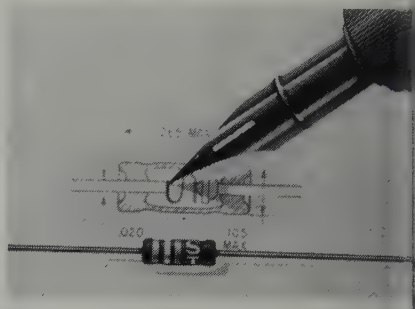

Silicon Readout Photocells

Designed specifically for computer and data processing equipment where rapid detection of light passing through punched cards or tape is required, International Rectifier silicon photovoltaic readout matrices feature extremely fast response time in the order of 10 microseconds. The self-generating devices convert light energy directly into electricity with no need for external power supplies. Typical current generated is 300 microamperes for 0.01 square inch of active cell area at 1,000 footcandles illumination.

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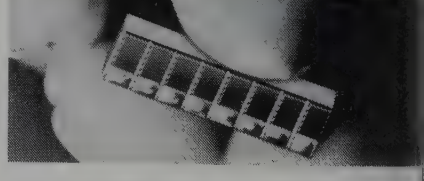


Tetrode Transistors

Two new germanium tetrode transistors for industrial and military applications are now being manufactured by General Electric. 3N36 and 3N37, are designed for use as wide band RF amplifiers, radar IF amplifiers, and high frequency mixers and oscillators. 3N36 has an operating range of 30 to 100-megacycles; 3N37—100 to 300-megacycles. Both transistors are capable of attaining maximum gain at power levels as low as five milliwatts.

Circle 126 on Reader Service Card

Power Supply

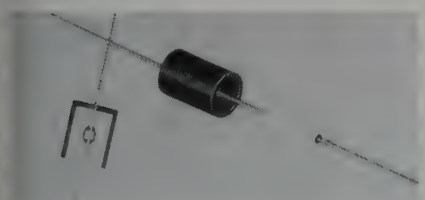
Highly versatile, stable and reliable, EICO Model 1020 is a completely transistorized, very low ripple, portable DC power and bias supply providing continuously variable output voltage monitored by a dual range voltmeter. It comprises a power transformer, full-wave silicon diode rectifier circuit, electrolytic capacitor input filter followed by a two-power transistor (2-2N256) cascaded filter circuit. The maximum permissible load current varies from 150 ma in the 0-12 V. range to 300 ma in the 24-30 V. range. The maximum ripple (120 cps) at full load is only 0.005%. The unit is housed in a rugged grey wrinkle steel case 5" x 4" x 5½" and is fused for protection against short circuits.

Circle 190 on Reader Service Card

Mass Production Diode Encapsulation

A new process, announced by Epoxy Products makes possible the use of mass production techniques in the encapsulation of diodes. Already in use by a number of diode manufacturers, the E-Pak system consists of an epoxy molded case and a yellow E-Form pellet with a step configuration that provides easy positioning of the diode. The diode is inserted into the assembled pellet and case. With the application of heat, the pellet melts and seals the unit. These epoxy packaged units are homogeneous and resistant to 95% relative humidity for 1000 hours.

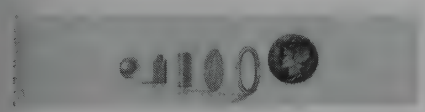
Circle 124 on Reader Service Card



Solder Preforms

A new line of soft solder preforms for automatic soldering at temperatures ranging from 158°F to 1800°F has been introduced by Alloys Unlimited, Inc. Manufactured from the solder systems of tin-lead, indium, silver, precious metals and fusible alloys containing bismuth and cadmium, the preforms are available as rings, discs, washers, pellets, castings, balls and spheres, and special shapes.

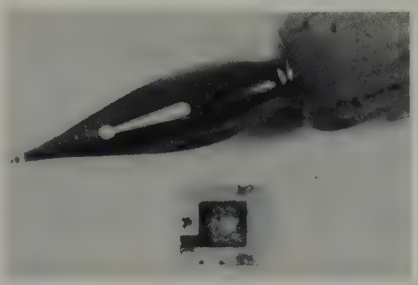
Circle 192 on Reader Service Card



Solid-Tantalum Capacitor

This tiny solid-electrolyte Tantalex Capacitor embedded in a notched phalanx-shaped ceramic wafer .3" square was developed by the Sprague Electric Company for use in the Signal Corp-RCA Micromodule Electronic Super-Miniaturization Project. Capacitances as high as 30μF at 1 volt or 10μF at 3 volts are contained in a wafer only 25 mils thick.

Circle 120 on Reader Service Card



Lead Straightener-Orienter

The Carman Lead Straightener-Orienter straightens diode leads between the plain surfaces of an air driven rolling mechanism. This mechanism is actuated manually or automatically. The machine's capacity is determined by the operator's ability to hand feed diodes into the drop-slot in the lucite cover or by the capacity of the succeeding machine. Typical operating speeds are around 3600 diodes per hour.

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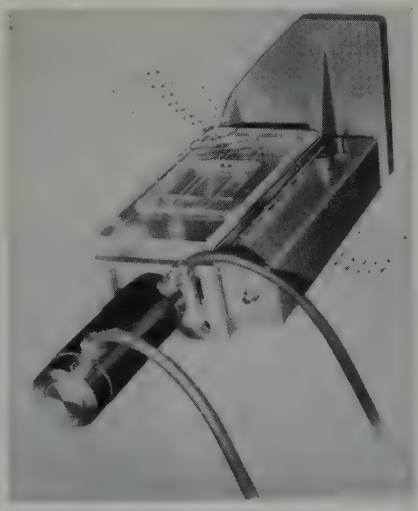
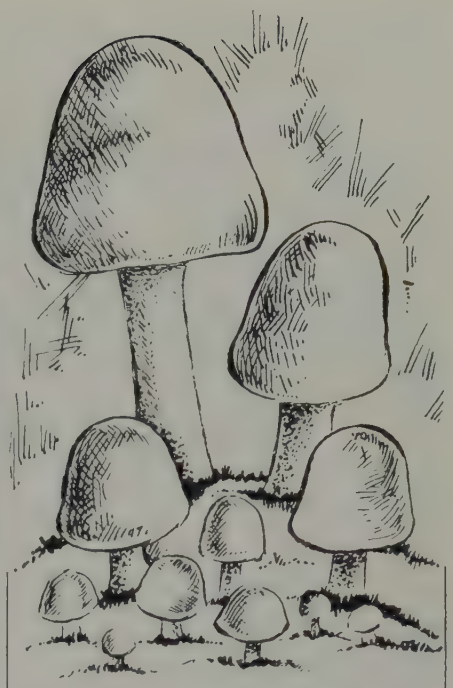


Transistor Package

Transitron Electronic Corp., announces a new package development in its high power silicon transistor line, the 2N1208, 2N1209, and 2N1212. The rugged stud-mounted package combines durability with performance. The 11/16" hex-nut single stud construction contributes to greater strength and ease of mounting, and electrical insulation of the device from heat sink is more readily accomplished. High temperature reliability is performed as an integral part of the manufacturing process.

Circle 123 on Reader Service Card

(Continued on page 73)



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Industry News

Conference Calendar

The following November 1959 IRE and Jointly Sponsored Meetings Are Scheduled:

Nov 3-5 MAECON (Mid-American Electronics Conference), Municipal Auditorium & Hotel Muehlebach, Kansas City, Mo. For Information: Dr. Sheldon Levy, Mid-West Res. Inst., 425 Volker Blvd., Kansas City, Mo. Sponsored By: Kansas City Section.

Nov 4-6 National Automatic Control Conference, New Sheraton Hotel, Dallas, Texas. For Information: George Axelby, Westinghouse, Box 746, Friendship Airport Station, Baltimore, Md. Sponsored By: PGAC, PGIE, Dallas Section, ISA, AIEE.

Nov 9-11 Radio Fall Meeting, Syracuse Hotel, Syracuse, N. Y. For Information: Virgil M. Graham, EIA, 11 W. 42nd Street, New York 36, N. Y. Sponsored By: IRE, EIA.

Nov 9-11 4th Instrumentation Conference, Atlanta, Georgia. For Information: W. B. Jones, Jr., School of E. E., Georgia Tech., Atlanta 13, Ga. Sponsored By: PGI.

Nov 10-12 12th Annual Elec. Tech. in Medicine & Biology Conference, Penn-Sheraton Hotel, Philadelphia, Pa. For Information: Dr. L. E. Flory, RCA Laboratories, Princeton, N. J. Sponsored By: PGME, AIEE, ISA.

Nov 16-19 Conference on Magnetism & Magnetic Materials, Sheraton-Cadillac Hotel, Detroit, Mich. For Information: Jack E. Goldman, Scientific Lab, Ford Motor Co., Box 2053, Dearborn, Mich. Sponsored By: IRE, AIEE, APS, AIM, ONR.

Nov 17-19 NEREM (New England Research & Engineering Meeting), Boston Commonwealth Armory, Boston, Mass. For Information: Drs. G. A. Norton & Ralph Miller, Avco Res. & Adv. Div., Lawrence, Mass. Sponsored By: Region 1.

Other Meetings Scheduled:

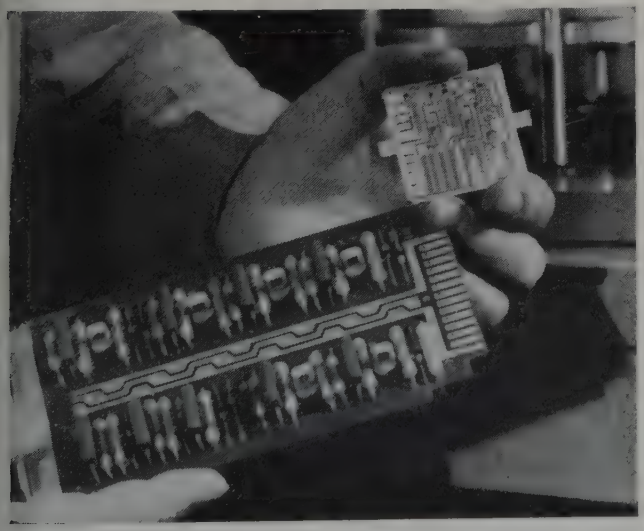
Nov 2-6 National Metal Exposition & Congress, International Amphitheatre, Chicago, Illinois.

Research and Development

Intensive studies on the unique properties of grain boundaries recently resulted in the design of a new semiconductor device, the grain boundary photo diode. In contrast to all other semiconductor devices now in the field which are made out of single crystals or polycrystaline material, the grain boundary devices make use of a dislocation plane which is set up in the interior of an n-type germanium or silicon bicrystal when it is grown out of

ne melt. The properties of such a dislocation or grain oundary plane may roughly be characterized by stating hat it acts like an extremely heavy doped, extremely arrow (10^{-4}cm) sheet of p-type semiconductor material f very high recombination velocity. The use of grain oundary photo diode as a displacement detector offers real dvantages to the design of photo electronic equipment. irst, it has the advantage of a symmetrical device and ither d.c. or a.c. may be used as a bias voltage. Use of a.c. oltage eliminates the need of compensating the dark cur- ent, when used as a displacement detector. This means reater circuit simplicity and reliability. Secondly, the rain boundary photo diode has a photo sensitivity greater han that of other commonly used devices by a factor of 10 r more. Values of 30 μA/foot-candles are typical. Another eature which may be most important in some applications s the nearly complete independence of its photosensitivity with decreasing temperature. Working at temperatures of liquid oxygen exhibits only a slight decrease in sensitivity which can completely be compensated by a slight increase n working voltage. Only the utmost simplicity of circuitry s needed to bring the grain boundary photo diode to proper operation, according to Nucleonic Products Co.

Sputtered thin-film resistors, formed from refractory metals such as tantalum and titanium, may be one of the more important developments in microminiature elec- ronics. Such resistors can be produced on glass or ceramic bases in lines as narrow as 1 mil (0.001 inch), spaced 1 mil apart, thus producing extremely high resistance in a small area, according to D. A. McLean, of Bell Telephone Labora- ories. Shown are the reduced size of a printed circuit using the newly developed sputtered resistors, and the comparable conventional printed circuit board. The small ceramic circuit card contains sputtered capacitors and con- necting leads, as well as the resistors, thus incorporating all the components appearing on the conventional board except the diodes, which can be attached by dip soldering techniques.



A new process for the preparation of high temperature semiconductors has been developed by Stanford Research Institute's ceramics technology group. The accomplishment consists of a method to produce high-purity, single crystals of silicon carbide, and promises to raise the temperature limits for transistor and diode operation from 400°F. to about 1800°F. About two years ago Dr. William Shockley theorized that silicon carbide crystals might be grown from solution in alloy melts. SRI's Frank A. Halden and his co-workers put the theory into practice. The result is a local- ized area of supersaturated solution from which silicon carbide crystals can be grown. At present, SRI-grown

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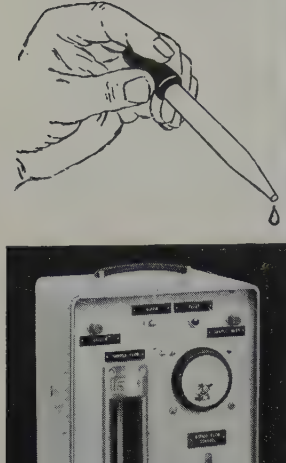

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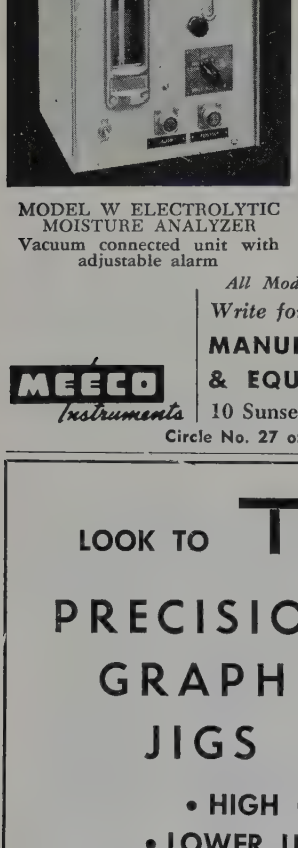

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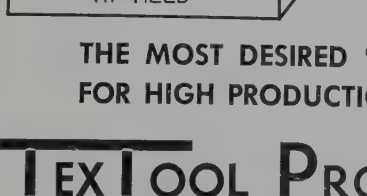

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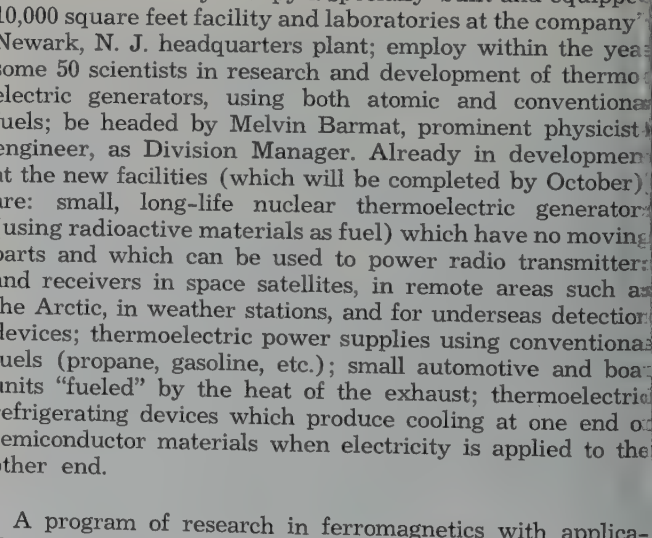
crystals are too small to be commercially usable. However, the process appears sufficiently promising and the Halder group plans to work with such variables as temperature, temperature gradients and crucible design to find optimum conditions for growing large crystals. When perfected, the new crystals should open a whole new field of uses for semiconductors.

Electronic tubes of the future may some day be "transistorized," according to Westinghouse scientists. An experimental electronic tube, under early development at the Westinghouse research laboratories, gets its all-essential supply of electrons from a tiny crystal of silicon carbide no larger than the head of a pin. The crystal replaces the hot, power-consuming cathode usually found in conventional electronic tubes. The tube depends upon a new form of electron emission discovered in a semiconductor material, silicon carbide. Successful application of the discovery would result in a "solid state" electronic tube that would combine into a single device many of the advantages both of semiconductors and vacuum tubes. The silicon carbide crystal is inside the cartridge being inserted into the tube.



Expanding into a new field of nuclear-semiconductor technology, General Instrument Corporation announced formation of a new, autonomous Thermoelectric Division which will: initially occupy a specially-built and equipped 10,000 square feet facility and laboratories at the company's Newark, N. J. headquarters plant; employ within the year some 50 scientists in research and development of thermoelectric generators, using both atomic and conventional fuels; be headed by Melvin Barmat, prominent physicist and engineer, as Division Manager. Already in development at the new facilities (which will be completed by October) are: small, long-life nuclear thermoelectric generators (using radioactive materials as fuel) which have no moving parts and which can be used to power radio transmitters and receivers in space satellites, in remote areas such as the Arctic, in weather stations, and for underseas detection devices; thermoelectric power supplies using conventional fuels (propane, gasoline, etc.); small automotive and boat units "fueled" by the heat of the exhaust; thermoelectric refrigerating devices which produce cooling at one end of semiconductor materials when electricity is applied to the other end.

A program of research in ferromagnetics with applications to storage devices was begun two years ago at Laboratory for Electronics, Inc., 1079 Commonwealth Avenue, Boston, Massachusetts. The research is being carried out by the Applied Physics Group of the Computor Products Division. The LFE Program includes a study of the micromagnetic properties of vacuum-evaporated thin films, and the dependence of these properties on other controllable or measurable characteristics. The primary practical objective of this research is the realization of a new class of storage and display devices depending on the detailed properties of domain walls and their motion. The work gives promise of making available storage devices of extreme compactness, ruggedness, and simplicity.

New Products

(from page 69)

Transistor Coolers

Available from Modine Mfg. Company in forced air flow and natural convection models, pre-designed, compact, lightweight, brazed all aluminum Transistor Coolers are offered in seven capacities. They may be ordered pre-drilled for any of the five standard transistor configurations and can be supplied in two finishes, MIL-C-5541 chromate or MIL-A-8625 black anodized. As many as six semiconductors can be accommodated by a single Cooler.

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Transistor Heat Radiators

A new series of transicool transistor heat radiators is announced by Mark Corporation. These reduce transistor temperatures by providing a greatly increased radiating surface. This, in turn, increases the life and improves the operating performance of the transistors. High conductivity copper is used for maximum conduction of heat. Aluminum is also available for applications where minimum weight is required. Available in sizes to fit all JEDEC-30 packaged transistors.

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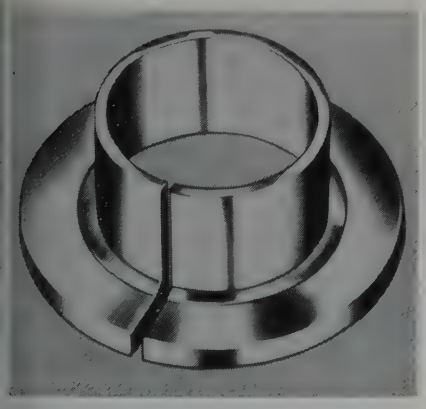

Semiconductor Alloy Kit

A semiconductor alloy kit, designated Z-100, including 24 different semiconductor alloys in various usable forms such as discs, spheres, and washers, in excess of 25,000 preforms, is available to the semiconductor industry from Accurate Specialties Company, Inc. as an aid in speeding development of new devices and processes. All alloys are packaged in argon for maximum shelf life, and are documented so that they can be reproduced at a later time in large lots to meet subsequent production quantities.

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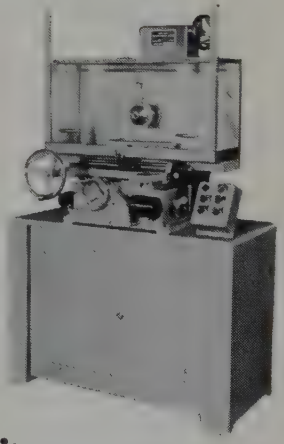

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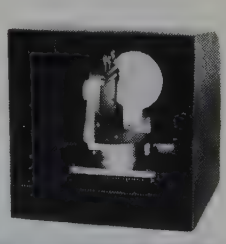

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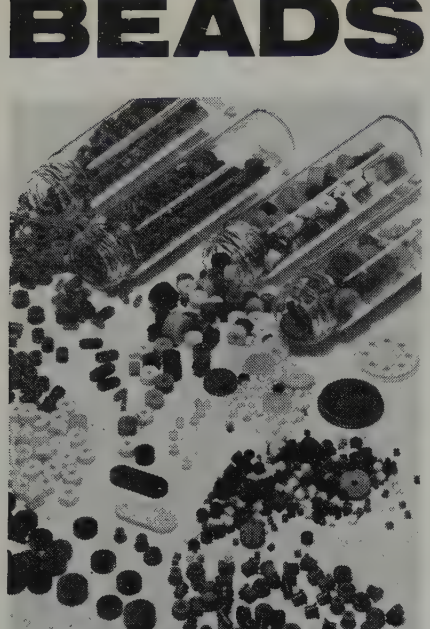

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Semiconductor Furnaces

Hevi-Duty Electric Company announces the availability of several standard precision furnaces for the transistor and semiconductor industries. These furnaces have proven highly successful in supplying the exacting temperature requirements necessary in the production of sensitive electronic components. They are available in three maximum temperature ranges: 1850°F, 2200°F, and 2600°F. Request Bulletin 459.

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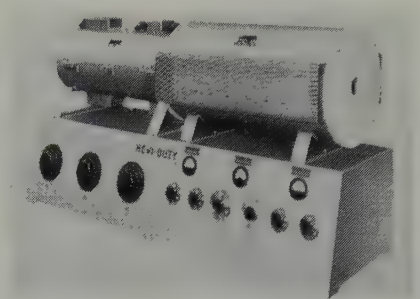

Zone Melting Apparatus

Model Z-81 Zone Melting Apparatus is a versatile machine that can be operated either horizontally or vertically for the purposes of zone refining, zone leveling and crystal pulling. MRC refinements make it an integrated, fully automatic, light weight machine which is safe and convenient to operate. Custom modifications are available to suit particular needs. Shock mounted on tubular frame, vibration free, light in weight and sturdy. Open construction allows easy access to all parts. It is completely equipped with a diffusion pump, vacuum valves, mechanical pump bypass and high vacuum valves. Manufactured by Materials Research Corp.

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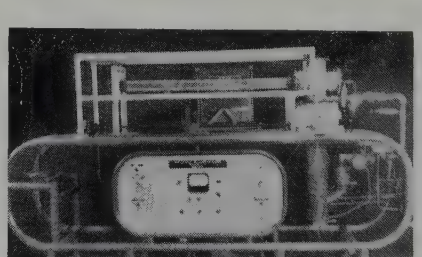

Diffusion Furnace

A new concept in diffusion furnace design with temperature control to within one degree centigrade. Inside dimensions 5″ x 5″ x 15″. 15″ effective heating length with a 2″ quartz tube. Ten inches of effective heating length is controlled to within plus or minus 1 degree centigrade. Now in use by the Continental Device Corp. These units are manufactured by A. D. Alpine, Inc.

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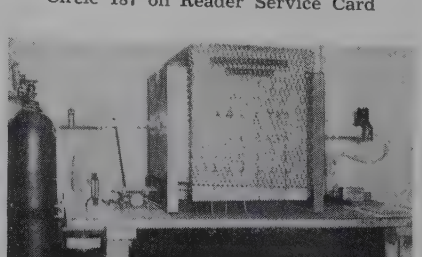

Heat Pump Test Kit

Model E-8 test kit designed to introd the fundamentals of thermoelectric h pump operation and to further exp mentation on possible heat pump appli tions has been announced by Minnes Mining and Manufacturing Co. Conta an assembled heat pump, 4 extra "p" t elements and 4 extra "n" type eleme A manual of data accompanying the contains instructions for the use of kit and suggested experiments, as well an explanation of thermoelectric h pumping and construction suggestions heat pumps of the operator's own des

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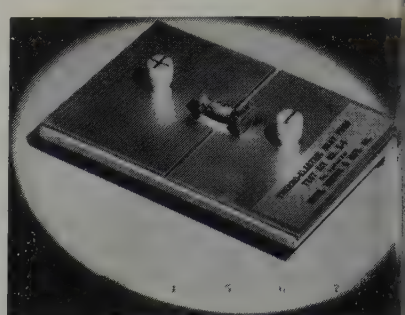

Power Supply

Trygon Electronics announces the ava ability of the "36" Silver Trygon Ser of transistorized, rack mounted pow supplies. Featuring a new Automa Protection System, this series furnish 0-36 Volts variable DC output at 1.5 Am 2.5 Amps, 5 Amps, 10 Amps and 15 Am with a 0.01% load regulation and 0.0 line regulation.

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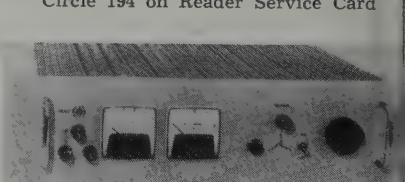

Program Controllers

The Redford Corporation has recen announced a new line of Sequential Pr gram Controllers. Designed for machi automation, these new programmers u solid state, cold cathode componen Their extremely versatile circuitry can adapted to almost any requirement. A sensing and control circuits employ tra sistors and transistor-driven rela Dimensions in standard 19″ relay rack approximately 24″ high, 22″ wide and 1 deep. Accessories: Magnetic picku infra-red beam pickups, stylus picku or special pre-amplifiers. All accessori obtain operation power from the progra mer itself.

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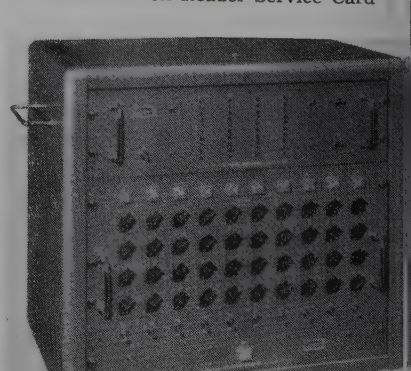

Silicon Power Rectifiers

Semiconductor Corp. of America, announces the new silicon power rectifier. Designed for high reliability, this new silicon power rectifier offers voltage ratings to 600 PIV and current rating to 18 Amps D.C. at 100°C ambient with forward drop of less than 0.8 volts. The hermetically-sealed construction features a silver anode lead and solid copper base for high thermal and electrical conductivity. For reliability assurance, each unit is temperature-cycled between —65°C and 200°C for six hours, leak tested, and load tested before shipment.

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Oxygen Leak

A simple leak based on the temperature controlled selective diffusion of oxygen through a silver thimble. Available from Thomason Chemicals, Inc. A high purity reagent grade of oxygen is obtained from room atmosphere by the specificity of the diffusion process. Leak rate is varied from 0 to 1 micron-liter/second. Control of leak is obtained by the variation of tube temperature. Leak may be used with ordinary air as input. Heater operates with 110 volt-low amperage variable transformer. No valves or stopcocks required for application. The leak is bakeable (to 450°C.) making it suitable for use even in the 10^{-10} mm. Hg. pressure range.

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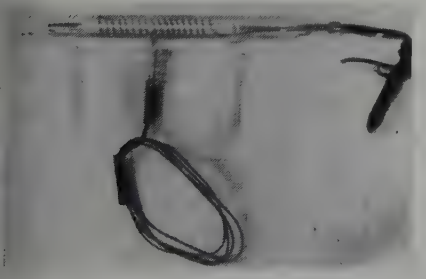

Silicon Rectifier Line

Bradley Semiconductor Corp., has added 2.5 and 12 amp Insulated Base Silicon Rectifiers to their 'Redtop' line. All units in the series meet military environmental specs. They have withstood high vibration of 20 G's up to 2000 cps and 50 G's shock. The amp rectifier features a surge rating of 240 amps and low leakage of 2 microamps (25°C).

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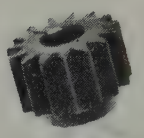

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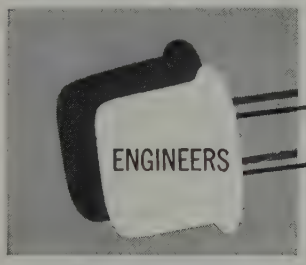

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Silicon Transistor Family

Philco Corporation has begun manufacturing 7 new NPN silicon transistors which permit practical complementary circuitry up to 100 mc and feature low collector capacitance. 2N1199 is intended for high-speed, high temperature saturated switching circuits at frequencies up to 5 mc. Top temperature is 150°C. 2N1267, 2N1268 and 2N1269 represent beta ranges of 6-18, 11-36 and 28-90, respectively, intended for 4.3 mc amplifier applications. 2N1270, 2N1271 and 2N1272 for 12.5 mc amplifier applications have the same three specific beta ranges.

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Semiconductor Product Series

Two new solar products introduced by the Semiconductor Division of Hoffman Electronics Corporation are forerunners of a new series of commercial products using Hoffman silicon solar cells. The devices are a subminiature "detector capsule" with an extremely sensitive silicon sensing element, and a light intensity-color temperature measuring instrument. Both use silicon light-to-energy converters similar to the Hoffman solar cells now generating power to operate instruments in the Vanguard I and Explorer VI satellites.

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Mesa Transistors

Two new Mesa transistors, 2N1300 and 2N1301, for high-speed switching in electronic computers were announced recently by RCA. RCA expects that the new transistors will become key components for high-speed military and commercial electronic data-processing equipment in the very near future. Technical features include: High-speed switching in saturation-type circuits, maximum power dissipation of 150 milliwatts at 25 degrees Centigrade, minimum collector-to-base breakdown voltage of —13 volts, typical gain-bandwidth product (figure of merit): 40 Mc for 2N1300 and 60 Mc for 2N1301, hermetically sealed in a JEDEC TO-5 case.

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Silicon Rectifiers

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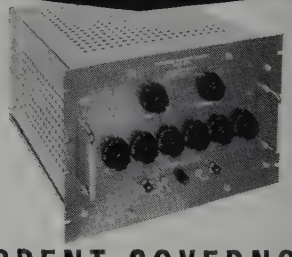

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PERSONNEL NOTES

Robert L. Ashley, president, announced the appointment of Laurence Le Bow as sales manager of Silicon Transistor Corp., manufacturers of silicon diodes and power transistors. Before coming to STC, Mr. Le Bow was assistant sales manager, semiconductor division, Radio Receptor Corp., a subsidiary of General Instrument Corp.

Robert H. Rich has been named sales manager for hearing aid products manufactured by Raytheon Company's Semiconductor Division. Mr. Rich, who has been with the company since his graduation from Newton Junior College in 1950, was most recently supervisor for the Semiconductor Division's Sales Service Department. His new office is at division headquarters, 215 First Avenue, Needham, Mass.

United States Dynamics Corporation announced that William L. Quine has joined their Semiconductor Products Division as General Manager. According to Dr. W. E. Strimling, President, the Corporation plans to expand its current line of semiconductor devices in keeping with the recent growth of its Industrial Equipment Division. Mr. Quine was formerly Manager of the Silicon Division of Bradley Semiconductor Corporation in New Haven, Connecticut.

Dr. Nicholas Fuschillo, a solid state and chemical physicist noted for his work in the fields of thermoelectricity and nuclear magnetic resonance, has joined CBS Laboratories to head its Solid State Physics Department, it was announced by Dr. Peter C. Goldmark, president of Solid State Physics Laboratories.

Appointment of Dr. Robert N. Noyce as vice president and general manager of Fairchild Semiconductor Corporation was announced by Richard Hodgson, executive vice president of Fairchild Camera and Instrument Corporation, the firm's sponsoring affiliate. Dr. Noyce's original position with Fairchild Semiconductor was director of research and development. He will continue his interest in this aspect of the firm. Dr. Noyce received his Ph.D. in physics at M.I.T. and worked in advanced semi-conductor research for four years prior to his co-founding of Fairchild Semiconductor.

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Dr. Earl L. Steele, a physicist expert in semiconductor devices, has been appointed assistant manager of the development laboratory for the semiconductor division of Hughes Aircraft Company's Products Group, it was announced by L. James Levisee, division manager. Dr. Steele, formerly research chief for Motorola, Inc., is the author of many technical papers on diodes, transistors and rectifiers, and serves as editor of the IRE Transactions on electron devices.

The appointment of Dr. J. Earl Thomas, Jr., eminent solid state physicist, to the newly created post of director of research and engineering for the Semiconductor Division of Sylvania Electric Products Inc. has been announced by William J. Pietenpol, divisional Vice President and general manager. Dr. Thomas joined the Sylvania organization on an adviso basis in January, completing the academ year at Wayne State University, Detro where he headed the Physics Dept. his new assignment he will be respo sible for all of the Division's product r search and engineering activities.

E. J. Brandt has been named man facturing manager at Audio Devices, In Rectifier Division, Santa Ana, Calif.

PATENT REVIEW *(from page 59)*

ends which bear against said body, means for mounting said leads in normally diverging relationship, and a collar surrounding said leads adjacent to the pointed ends thereof to restrain divergence therebetween.

December 11, 1956

2,773,923 Zone Refining Apparatus—G. G. Smith. Assignee: Raytheon Manufacturing Company. Apparatus comprising an elongated body of electrically conductive material having a recess therein adapted to receive the substance to be zone refined, means for supplying heat only to a narrow zone in said body, means for successively applying said first means to successive narrow zones in said body whereby narrow zones in said substance may be melted.

2,773,925 Electrical Translator and Methods—B. J. Rothlein, F. A. Stahl. Assignee: Sylvania Electric Products Incorporated. A method of producing a localized inhomogeneity in a germanium body by exposing the surface thereof to the action of a zinc granule at a temperature of 600°C to 800°C, cooling said body, and etching the germanium to remove the zinc-germanium reaction products.

2,773,945 Transistor Signal Amplifying Circuits—C. T. Theriault. Assignee: Radio Corporation of America. Tuned, variable-gain transistor signal amplifying circuits wherein a substantially flat response is achieved over the frequency band at which the amplifying circuits operate with variations in the input resistance of the transistors.

2,773,981 Amplitude Sensitive Multistate Device—W. M. Goodall. An amplification device having input and output circuits; circuit control means for abruptly changing the conduction state of said device, said means including a shunt impedance, a reference potential point, and two asymmetrically conducting devices; and means for biasing at least one of said asymmetrically conductive devices in the low resistance state.

2,774,021 Electrical Motor Control Apparatus—R. J. Ehret. Assignee: Minneapolis-Honeywell Regulator Company. In combination: a single stage common emitter transistor amplifier and means for rendering it conductive in the absence of a input signal, a two phase reversible in duction motor having power and contr windings, and means for connecting sa control winding in shunt with the outp of said amplifier.

December 18, 1956

2,774,695 Process of Fabricating Germani um Single Crystals—J. A. Burton. A signee: Bell Telephone Laboratories. method of fabricating a single germaniu crystal body of predetermined lengt with uniform resistivity characteristi along said length, and higher injecte carrier lifetime characteristic in one por tion thereof than another portion, sai method comprising adding an amount o nickel not exceeding 0.001% by weigh to said other portion.

2,774,826 Stabilized Transistor Amplifier-J. M. Moulon. Assignee: None. A stabili ized two-stage transistor amplifie adapted to be power-supplied from a sin gle direct current source.

2,774,866 Automatic Gain and Ban widt Control for Transistor Circuits—F.

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Burger. Assignee: Emerson Radio & Phonograph Corporation. A transistor radio receiver comprising a converter stage, an *i-f* amplifying stage, a transformer for coupling said stages, and an automatic gain control voltage connected to said amplifier stage.

2,774,875 Wave Generating Network—E. Keonjian, J. J. Suran. Assignee: General Electric Company. In an active periodic wave generator: a re-entrant network comprising two cascade-connected transistor amplifiers; and means supplying electric energy to the operating electrode of said transistor amplifiers.

2,774,878 Oscillators—J. L. Jensen. Assignee: Minneapolis-Honeywell Regulator Company. Electronic apparatus for converting a direct current to an alternating current.

2,774,887 Radiation Sensing Device—R. C. McMaster, M. D. Phillips. Assignee: The Haloid Company. An X-ray detector comprising a voltage source, an electric circuit including a selenium element, means for detecting changes in electrical resistance of said element upon irradiation thereof with electromagnetic energy in the X-ray region of the spectrum.

2,774,888 Electronic Switch—R. B. Trousdale. Assignee: General Dynamics Corporation. A switch comprising a semiconductive device, a contact circuit, means associated with said control circuit for enabling said device to pass electrical signals, and means for maintaining the value of current in said control circuit constant regardless of the instantaneous value of the signal passed by the switch.

December 25, 1956

2,775,023 Manufacture of Small Rectifier Cells—L. K. Hedding. Assignee: Westinghouse Air Brake Company. A method of producing selenium cells which comprises providing a selenium coated base plate, removing the selenium layer from regions surrounding predetermined areas of the layer, filling said areas with an insulating compound, forming the barrier layer, applying the counterelectrode, and subdividing the base plate in the filled regions to produce a plurality of individual rectifier cells.

2,775,697 Crystal Diode Coincidence Circuit—R. Madsy. Assignee: U.S.A., (A.E.C.). A coincidence circuit operable on very low voltage input signals and including discriminating means for distinguishing minute variations between coincident input signals and other input signals.

2,775,705 Transistor Mixing Circuit—A. J. van Overbeek. Assignee: Hartford National Bank and Trust Company. A mixing circuit that includes a transistor having a base current-base voltage characteristic curve exhibiting two points of curvature of which one is at a relatively maximum value of base current and the other is at a relatively minimum value of base current, and a base electrode potential midway between said two points of curvature of said curve.

2,775,714 Variable Impedance Output Circuit—D. L. Curtis. Assignee: Hughes Aircraft Company. A device designed to provide a variable impedance output circuit for preventing unwanted signal components present in an applied variable voltage intelligence signal from appearing in a corresponding output signal from the circuit.

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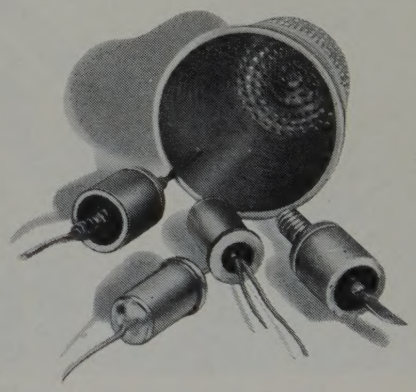

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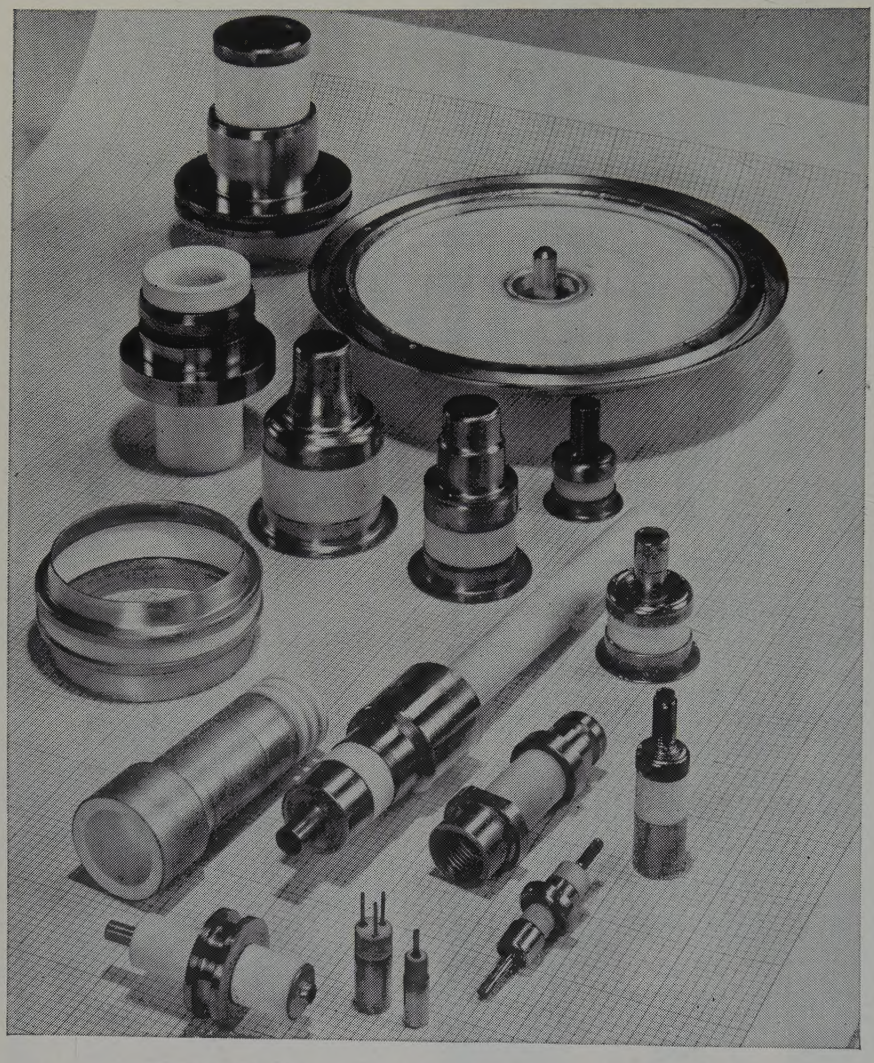

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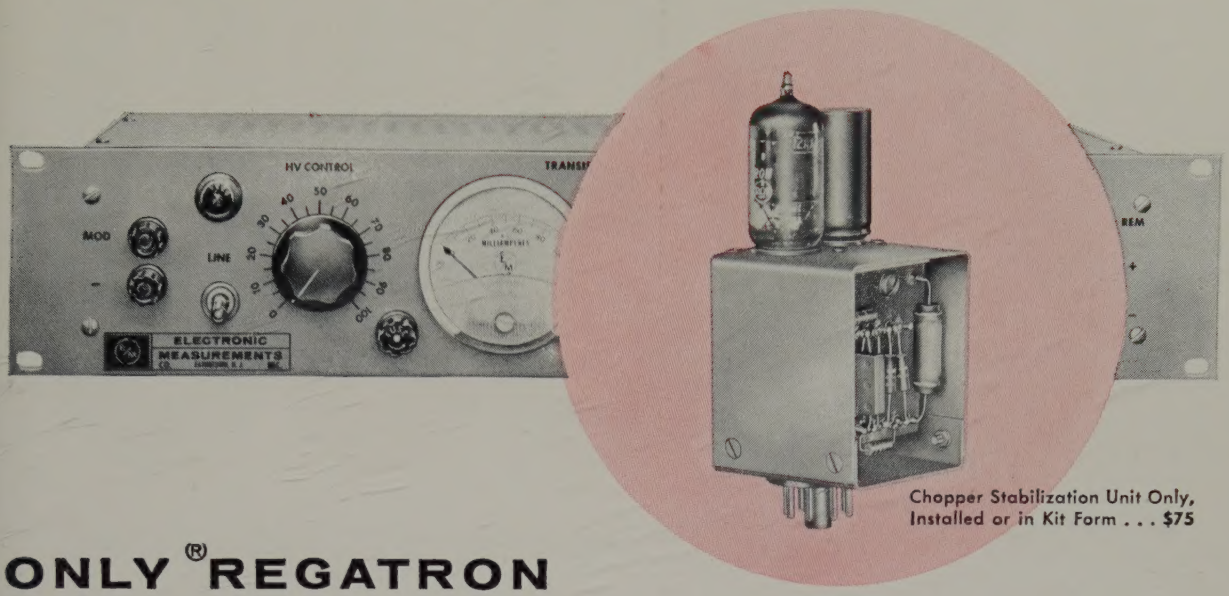

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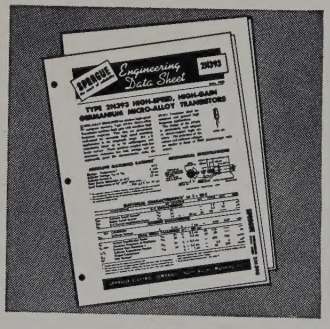

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2N393

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